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The effects of different aphid foods on *Adalia bipunctata* L. and *Coccinella 7-punctata* L.

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SUMMARY

The influence of different aphid foods on larval development and adult fecundity of *Adalia bipunctata* L. and *Coccinella 7-punctata L.* was investigated. Certain aphids such as *Myzus persicae* Sulz. and *Acyrthosiphon pisum* Harris were suitable for both species. *Megoura viciae* Buckt., was toxic to *A. bipunctata* but not to *C. 7-punctata. Aphis fabae* Scop., although a common natural prey of *A. bipunctata*, slowed larval development, partly because it was nutritionally unsuitable. Fecundity of adults fed on *A. fabae* was also reduced to less than half. Larvae and adults of *C. 7-punctata* developed and reproduced as well on *A. fabae* as on other suitable aphids.

C. 7-punctata caught aphids more quickly than *A. bipunctata*. Larvae of both species given relatively unsuitable prey fed more slowly than normal and consumed less of each aphid. The toxic aphid *M. viciae* was rejected by *A. bipunctata* after a short period of feeding.

INTRODUCTION

The Coccinellidae are the best known of all insect predators and also the most adequately recorded. Hodek (1959) has shown that the reported polyphagy of many aphidophagous coccinellids may result from the failure of investigators to distinguish between acceptability and suitability of their food. The purpose of this work was to investigate differences in suitability of various species of aphid to two common aphidophagous coccinellids, *Adalia bipunctata* L. and *Coccinella 7-punctata* L. These two species are recorded (Schilder & Schilder 1928) as feeding on a wide range of aphids, but Hodek's work (1956, 1957, 1959) indicates that only a limited number of species provide suitable food. Some preliminary data have already been published (Blackman, 1965).

MATERIALS AND METHODS

Laboratory cultures of *A. bipunctata* and *C. 7-punctata* were maintained and treated experimentally in a constant-temperature room at 20° C. with a 16 h. photoperiod. Coccinellid larvae were reared separately to avoid cannibalism. The aphids *Acyrthosiphon pisum* Harris, *Aulacorthum circumflexum* Buckt., *Myzus persicae* Sulz., *Megoura viciae* Buckt, and *Aphis fabae* Scop. were cultured on the broad bean, *Vicia faba*. Cultures of *Myzus persicae* and *Brevicoryne brassicae* L. on Brussels sprouts, *Brassica*

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oleracea gemmifera, were also used. *Aphis sambuci L.*, *A. fabae* and *Microlophium evansi* Theo. were collected from field populations on *Sambucus nigra* L., *Euonymus europaeus* L. and *Urtica sp.* respectively.

RESULTS

Larval development of Adalia bipunctata

Fig. 1 compares the increase in live weights of larvae fed on six aphid species. Larvae of *Adalia bipunctata* developed equally quickly on *Aulacorthum circumflexum*, *Myzus persicae*, *Acyrthosiphon pisum* and *Microlophium evansi*, but the other two species, *Aphis fabae* and *A. sambuci*, significantly slowed the rate of development. Data

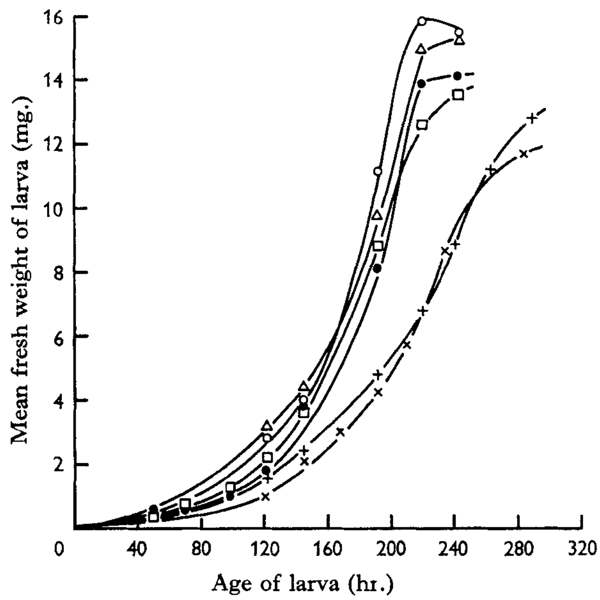

Fig. 1. Development of *Adalia bipunctata* larvae on different aphid foods. ○, *Microlophium evansi;* △, *Acyrthosiphon pisum;* ●, *Aulacorthum circumflexum;* □, *Myzus persicae;* +, *Aphis sambuci:* ×, *Aphis fabae.*

on larval mortalities and weight of resulting adults (Blackman, 1965) also indicate that *A. fabae* and *A. sambuci* are relatively inferior food. *A. fabae* was equally inferior whether reared on *Euonymus europaeus* or on *Vicia faba.*

Daily estimates were made of the weights of different aphid species eaten by developing larvae. Two sets of small, polythene-stoppered vials, numbered to correspond with the rearing cells, were used for weighing. Enough appropriately sized aphids (small for small larvae, etc.) to supply food for 24 h. were placed in one set of vials. The weights of vials plus contents were recorded, and the aphids were then given to the larvae in appropriate rearing cells. After 24 h. the aphids and aphid remains in each cell were returned to the corresponding vial, which was then reweighed. A weighed quantity of fresh aphids was then added to each cell from the second set of vials. Thus, the two sets of vials were used on alternate days to weigh the food presented to the larvae and the remains after 24 h. A measure of the weight of food taken daily was obtained by subtracting one day's readings from those of the preceding day. A correction was applied to the data to compensate for the change in weight of the aphids during the 24 h. period, but no allowance was made for water loss from the aphid remains. The results (Fig. 2) provide a comparison of the relative weights of the different aphids consumed.

The slower rate of development of larvae fed on *A. fabae* was correlated with a slower consumption of food. The total fresh weight of food eaten during larval development was, however, similar for all aphids (*A. circumflexum* 62·2 ± 6·6 mg.;

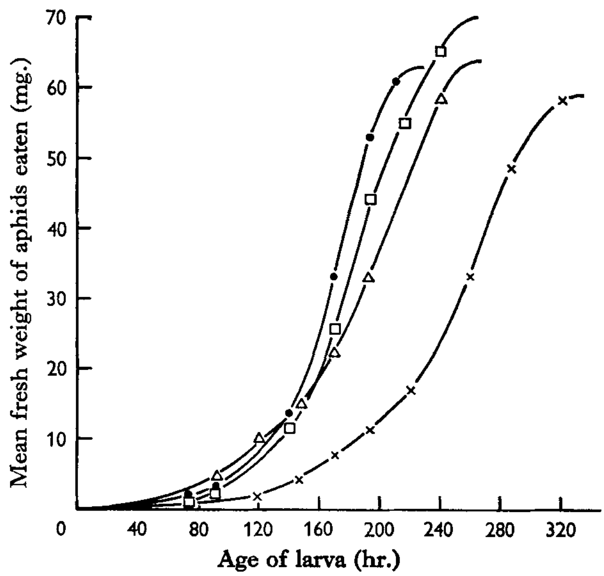

Fig. 2. Rate of consumption of different aphids by larvae of *Adalia bipunctata*. ●, *Aulacorthum circumflexum;* □, *Myzus persicae;* △, *Acyrthosiphon pisum;* ×, *Aphis fabae.*

M. persicae 69·1 ± 11·2 mg.; *A. pisum* 63·8 ± 4·6 mg.; *A. fabae* 57·8 ± 6·3 mg.). About 80 % of the total food eaten was consumed by the 4th instar. Larvae of *A. bipunctata* fed on *M. viciae* all died in the 1st instar before they were 2 days old. Experiments described later show that this aphid is eaten, but is toxic (cf. Dixon, 1958). *B. brassicae* is also unsuitable for *A. bipunctata.* Two out of six larvae given *B. brassicae* became adult, taking 21 and 23 days respectively from hatching to pupation (normal development time = 9·6–10·7 days). The adult weights at emergence were 5·1 and 6·1 mg. compared with the normal 10–13 mg. Both died within a week.

Larval development of Coccinella 7-punctata

The increase in weight of *C. 7-punctata* larvae given different foods is illustrated in Fig. 3. In contrast to *A. bipunctata*, larvae developed as quickly on *A. fabae* as on any other aphid. The larvae also developed to maturity on *M. viciae* and *B. brassicae*, but more slowly than on the other aphids. The rate of development of larvae fed on

M. persicae was the same irrespective of whether this aphid was reared on *B. oleracea* or *V. faba.*

Larvae took a mean of 16·1 days to develop on *B. brassicae*, and 26·1 % died. The mean weight of adults at emergence was 30·9 mg. This compares with 14·8 days, 13·4 % and 33·5 mg. respectively for *M. viciae* and about 13–14 days, 6–26 % and 36–37 mg. respectively for suitable aphid species (Blackman, 1965). The increased development time of larvae feeding on *M. viciae* and *B. brassicae* was due primarily to slow growth of the 1st and 2nd instars.

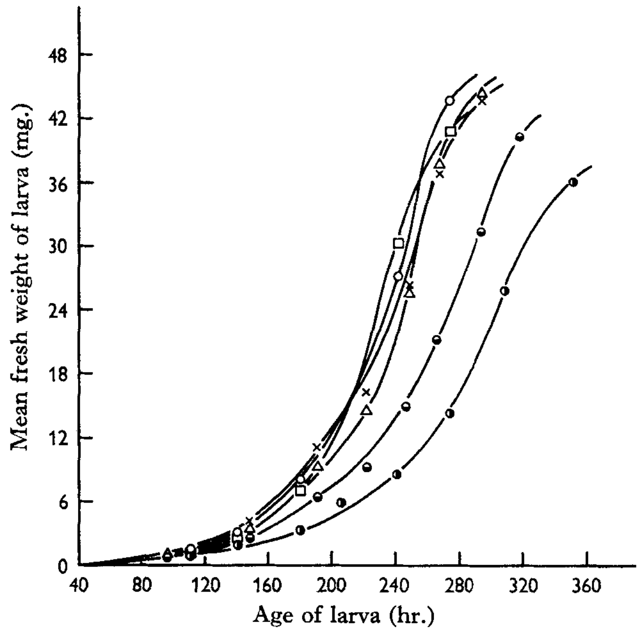

Fig. 3. Development of *Coccinella 7-punctata* larvae on different aphid foods. □, *Myzus persicae* (Brassica); ○, *Myzus persicae* (Vicia); △, *Acyrthosiphon pisum*; ×, *Aphis fabae;* ◒, *Megoura viciae;* ◑, *Brevicoryne brassicae.*

Six out of a group of twelve larvae fed on *A. sambuci* completed their development. They took a mean of 19·5 days, and the resulting adults were very small, with a mean weight of 18·4 mg. at emergence. However, Hodek (1956, 1957) found that *A. sambuci* was lethal to larvae and young adults of *C. 7-punctata.*

Feeding of adult Adalia bipunctata

Fig. 4*a* compares the effect on fecundity of rearing both the larvae and the adults of *A. bipunctata* on *A. fabae* and on *M. persicae.*

Those fed on *A. fabae* were less than half as fecund, and their eggs, were significantly smaller and less fertile, than those fed on *M. persicae* (Table 1).

Further batches of larvae were reared on these two aphid species, the emerging adults being fed on the opposite food to that given to the larvae. Thus adults developing from larvae reared on *A. fabae* were given *M. persicae*, and adults from *M.*

persicae fed larvae were given *A. fabae*. Fig. 4*b* shows that the food given to the larva did not affect the fecundity of the adult, which depended entirely on the food eaten in the adult stage.

Acyrthosiphon pisum seemed to be a suitable food for adult *A. bipunctata*, and eggs were laid, but its effect on fecundity was not recorded. *Megoura viciae* was toxic to adult *A. bipunctata*, which all died within a week of emergence.

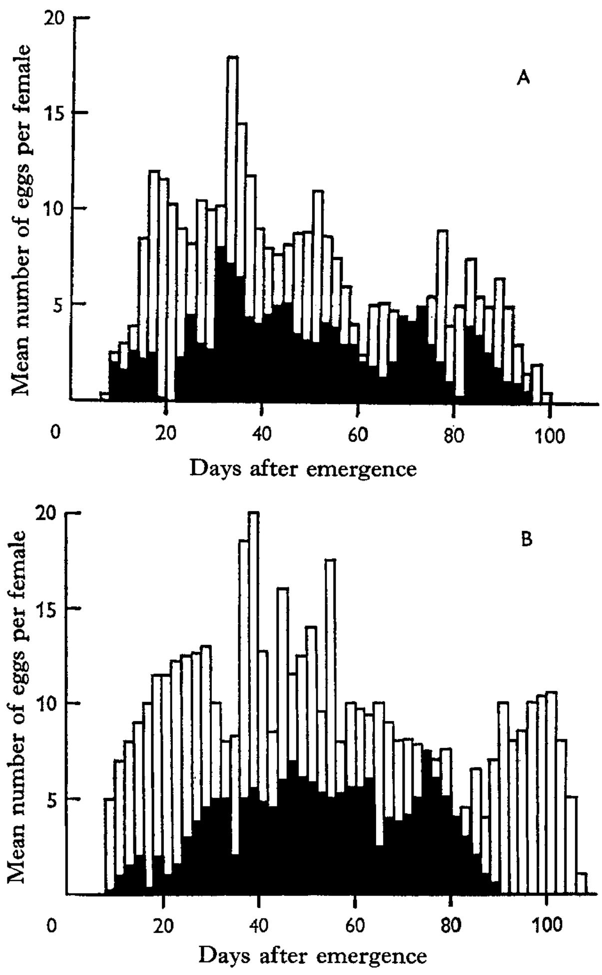

Fig. 4. Comparison of the fecundity of *Adalia bipunctata* fed on *Aphis fabae* and on *Myzus persicae*. A, Larvae reared on same food as adult; B, larvae reared on opposite food to adult. □, *Myzus persicae*; ■, *Aphis fabae*.

Fecundity of adult Coccinella 7-punctata

Four groups of adult *C. 7-punctata*, reared as larvae on *A. pisum*, were given different diets: (1) *Myzus persicae*, (2) *Aphis fabae*, (3) *Acyrthosiphon pisum*, and (4) *A. pisum* plus pollen. In (4), male catkins of hazel (*Corylus* sp.) and, later, willow (*Salix* sp.), were suspended in the boxes and replaced daily. The results of this experi-

Table 1. *Fecundity of* Adalia bipunctata *fed on* Myzus persicae *and on* Aphis fabae (*larvae given same food as adults*)

	Myzus persicae	*Aphis fabae*
Mean emergence weight of females (mg.)	10·7 ± 0·9	8·9 ± 0·7
Mean longevity of females (days)	76·2 ± 28·0	83·0 ± 36·3
Mean total eggs laid	676·2	249·6
Mean eggs per female per day	6·9	2·6
Mean egg length (mm.)	1·04 ± 0·02	0·99 ± 0·01
Mean egg breadth (mm.)	0·48 ± 0·01	0·46 ± 0·01
Percentage of eggs fertile	89·4	55·9

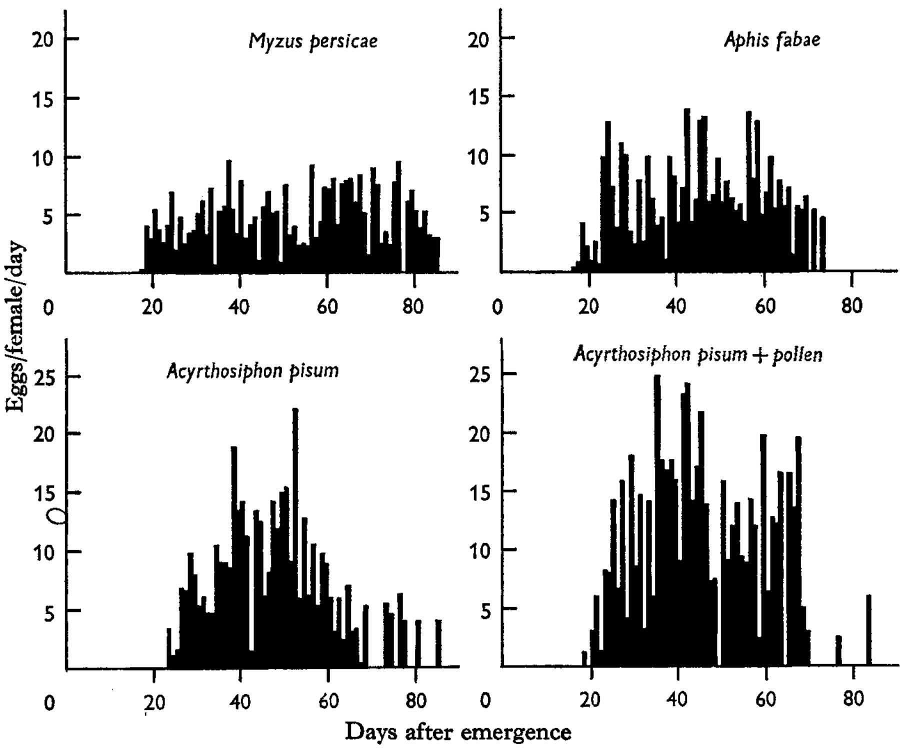

Fig. 5. The effect of different diets on the fecundity of *Coccinella 7-punctata*.

ment are illustrated in Fig. 5. The only significant difference in fecundity at the 5% probability level was between adults fed on *M. persicae* and those fed on *A. pisum* plus pollen. There was no well-defined peak in the oviposition of females fed on *M. persicae*, but laying was maintained over a longer period. The size of eggs laid by females fed on *A. fabae* and *M. persicae* did not differ significantly, but the fertility of eggs from females fed on *A. fabae* was significantly less than in the other three groups (69% compared with 80–86%). Beetles in group 4 fed frequently on pollen even with aphids abundant. Their peak laying period was longer than that of beetles fed on *A. pisum* alone, but the fecundity was not significantly different.

Adults reared from larvae fed on *B. brassicae* were also given *B. brassicae* in the adult stage. This species seemed to be suitable food for adult *C. 7-punctata*, and eggs were laid, but no records of fecundity were made. Four males and four females from larvae reared on *A. fabae* were given *M. viciae*. They died within 8 days; but ten males and ten females fed on *M. viciae* as larvae and as adults were more successful. Ten were alive after 30 days and two lived for 90 days, but no eggs were laid.

Aphis fabae *as food for* Adalia bipunctata

It is noteworthy that *A. fabae*, a common prey of *A. bipunctata* in Britain, is relatively unsuitable as food for larvae and adults of this species. This unsuitability was investigated in a quantitative comparison of *A. fabae* and *M. persicae* as food for 4th-instar larvae of *A. bipunctata*. Open 3×1 in. tubes were fitted with an internal scaffolding cut from Bristol Board, to give a large absorbent surface area, and a thin coat of Fluon was painted around the inside of the rim to prevent the insects from escaping. The tubes were kept in desiccators at 50 % R.H. and weighed at equilibrium.

One-day-old 4th-instar larvae, reared on either *A. fabae* or *M. persicae*, were kept without food overnight and then weighed and placed in the tubes, together with weighed amounts of the appropriate aphids, about 50 mg. per predator. Tubes with aphids alone and predators alone were used as controls. All tubes were kept for 24 h. in the desiccators at a constant temperature at 20° C. and then weighed. The coccinellid larvae, live aphids and aphid remains were then removed from the tubes and weighed separately. Predator faeces were ignored as they adhered to the scaffolding and sides of the containers. Dry weights were obtained by drying to constant weight over phosphorus pentoxide at 100° C.

The weight of aphids killed by a larva was estimated by subtracting the weight of aphids left alive in the experimental tubes from the initial weight of aphids presented after correcting for weight lost during the experiment. The weight of food ingested by the predator was calculated by subtracting the weight of aphid remains from the weight of aphids killed. An estimate of the proportion of each aphid attacked which was ingested, here termed the 'feeding efficiency', was thus possible

$$\text{Feeding efficiency} = \frac{\text{dry wt. of aphids killed} - \text{dry wt. of remains}}{\text{dry weight of aphids killed}} \times 100.$$

The 'growth efficiency' of 4th-instar *A. bipunctata* larvae feeding on each aphid species was estimated from the increase in weight of the predator and the weight of food ingested:

$$\text{growth efficiency} = \frac{\text{increase in dry weight of predator}}{\text{dry wt. of aphids killed} - \text{dry wt. of remains}} \times 100.$$

The values of feeding efficiency and growth efficiency are compared in Table 2. *A. bipunctata* larvae feeding on *A. fabae* consumed less of each aphid which they captured, and the material which was ingested was apparently less nutritious than that obtained from *M. persicae*.

It was also noted that larvae fed on *A. fabae* contained more water (wet weight/dry weight ratio $4{\cdot}66 \pm 0{\cdot}22$, as against $3{\cdot}88 \pm 0{\cdot}16$ for *M. persicae*).

The active pumping of digestive fluids into and out of the aphid body, which is a feature of the feeding behaviour of coccinellid larvae (Hawkes, 1920; Banks, 1957;

Kaddou, 1960), did not generally occur in *A. bipunctata* when the prey was *A. fabae*. The normal behaviour of 4th-instar *A. bipunctata* feeding on nymphs and adults of *M. persicae* and other suitable aphids entails (1) extra-oral digestion, with injection of digestive enzymes alternating with the sucking out of body-fluids and partially digested material, and (2) partial or complete ingestion of the solid remains. Fourth-instar *A. bipunctata* only did this to a young nymph of *A. fabae*. With older nymphs and adult *A. fabae*, the active pumping was replaced by a relatively passive sucking at the wound. The corpse of the aphid was then left fairly intact although somewhat deflated. These corpses were examined in longitudinal sections and compared with similar sections of uneaten aphids. Salivary glands, gut and fat-body were removed by the predator, but muscles appeared to be unaffected. Many neurones had gone from the brain and suboesophageal ganglion although the neurilemma was unaffected. The embryos of some aphids had been broken up and some contents had gone, but most were unaffected.

Table 2. *Comparison of values for 'feeding efficiency' and 'growth efficiency' for* Adalia bipunctata *4th-instar larvae fed on* Myzus persicae *and on* Aphis fabae

Species of aphid used as food	Feeding efficiency	Growth efficiency
Myzus persicae	40·1 ± 5·0	44·9 ± 6·7
Aphis fabae	23·6 ± 4·5	28·1 ± 3·2

Table 3. *Amino acid analysis: percentage composition of samples*

The last column shows the percentage of the amino acid available in *Aphis fabae* that is consumed by a larva feeding on this aphid.

	A. bipunctata 4th-instar larvae	*Myzus persicae*	*Megoura viciae*	*Aphis fabae*	*A. fabae* remains	
Serine/glycine	19·88	19·41	19·12	19·91	19·75	32·4 %
Arginine/lysine/histidine	15·33	16·98	16·71	14·74	15·63	27·1 %
Leucine/phenylalanine	14·30	14·37	12·63	15·24	13·83	37·6 %
Glutamic acid	11·29	10·61	14·23	13·21	12·91	31·9 %
Alanine	10·84	13·64	11·57	10·63	13·05	16·1 %
Aspartic acid	8·20	6·50	9·14	10·36	9·65	36·8 %
Valine/methionine	8·91	8·30	7·39	7·51	8·55	21·8 %
Threonine	5·22	6·25	4·75	4·40	3·73	39·2 %
Tyrosine	4·94	2·89	3·44	2·58	1·27	66·2 %
Cysteine	1·09	1·02	1·01	1·38	1·49	27·8 %

There thus appeared to be limited extra-oral digestion. The cuticle of the adult *A. fabae* was almost twice as thick as that of the adult *M. persicae*. A thick cuticle would hamper the active pumping in and out of material and also hinder the final mastication and ingestion of the solid remains.

To test whether the *A. fabae* diet was deficient in amino acids, the total amino acid composition of *A. fabae* remains after predation by 4th-instar *A. bipunctata* larvae was compared, using two-way paper chromatography, with that of whole *A. fabae*, other species of aphid, and the predator itself (Table 3). The percentage of each amino acid consumed by a predator feeding on *A. fabae* was calculated taking 24 % as the proportion of a whole aphid consumed (dry weight). It is apparent that both predator and prey are closely similar in their amino acid composition, and that no one amino acid is left in significant quantities in the *A. fabae* remains. A relatively small proportion of the alanine present in the whole aphid is ingested by the predator, but it is not known whether this represents a deficiency.

Feeding behaviour of Adalia bipunctata *and* Coccinella 7-punctata *larvae*

Observations were made of 1st- and 4th-instar larvae of the two Coccinellid species feeding on four aphid species: *Myzus persicae*, *Aphis fabae*, *Acyrthosiphon pisum* and *Megoura viciae*. Aphids of known weight were presented to the predator and the time spent in feeding on the prey and the percentage weights of the prey eaten were recorded. Unfed 1st-instar larvae were used, approximately 12 h after dispersion from the egg cluster. The 4th-instar larvae were reared on the species of aphid used in the experiment, allowed 3–4 h. feeding after the 3rd/4th-instar ecdysis, and then left without food overnight. Each predator was used only once.

All weighings were done on a Cahn-Gram electro-microbalance. Young nymphs of *c.* 0·3 mg. were given to the 1st-instar predators, and nymphs of approx. 0·5 mg. to 4th-instar predators, the instar depending on the species of aphid. Groups of twenty aphids, differing in individual weight by less than 5 %, were given to each predator in the lid of a 2 in. plastic pill-box, the sides of which were coated with Fluon. Each experiment was replicated about ten times. Records were made of (1) the time taken to make an effective capture, (2) the number of potential prey encountered (i.e. touched by forelimbs or mouthparts) before and including the first effective capture, (3) the time spent feeding, from insertion of the mouth parts into the body of the aphid until either complete ingestion of the prey or abandonment of the remains, (4) the wet weight of the aphid remains left, and (5) the dry weight of the remains. Observations were also made of the method of capture of the prey and the behaviour of the prey whilst feeding. Once a capture had been made the rest of the aphids in the lid were removed to avoid disturbance of the predator whilst feeding. The remains of the aphid left after feeding were weighed immediately to get a value for wet weight before significant water loss occurred. From the wet weight and dry weight of the remains left after predation, the percentage of wet weight and dry weight eaten were estimated.

The time taken to make an effective capture, and the number of potential prey encountered in this time, indicate the efficiency of the predator in capturing its prey, although results obtained under highly artificial conditions such as these must be treated circumspectly. The time spent feeding and the weight of aphid remains left are less likely to be affected by the conditions of the experiment, and in confirmation of this some records made of larvae feeding on aphids on their food plant agreed closely with the results obtained here.

Adalia bipunctata: *1st instar*

First-instar larvae of *A. bipunctata* rarely captured at the first encounter and generally took several minutes to capture an aphid (Table 4*a*). The larvae found *Acyrthosiphon pisum* most difficult because of its rapid escape reactions. In exactly half of the observed captures of *A. pisum*, the predator caught a tarsus, and was dragged around for some time before it managed to grip the body of the aphid. *M. viciae* was also difficult to catch, but once a capture had been made feeding began at once; yet the prey was soon released (Table 4*a*), and on examination the predator was found dead or dying. *M. viciae* thus has a very rapid toxic effect on 1st-instar larvae of *A. bipunctata*. Feeding on *M. persicae* and *A. pisum* took about 2 h. during, which most of the prey was consumed. When the prey was *A. fabae*, feeding lasted about 6 hr. and relatively little was eaten.

Table 4. *Feeding behaviour of* Adalia bipunctata

Prey	No. of replicates	Mean time before 1st capture (min.)	Mean no. of prey encountered	Mean time spent feeding (min.)	Wet weight eaten (%)	Dry weight eaten (%)
		(*a*) 1st-instar larvae				
Myzus persicae	10	3·6	2·5	128·0	85·8	63·1
Aphis fabae	13	2·6	1·5	379·0	30·4	12·7
Acyrthosiphon pisum	12	13·9	4·5	116·3	80·6	79·0
Megoura viciae	4	7·5	3·5	13·5	—	—
		(*b*) 4th-instar larvae				
Myzus persicae	13	1·1	3·9	8·7	95·4	87·4
Aphis fabae	11	1·7	2·5	43·4	86·1	61·5
Acyrthosiphon pisum	12	2·5	3·6	9·1	95·8	88·0
Megoura viciae	10	0·8	3·6	4·1	29·0	16·4

Table 5. *Feeding behaviour of* Coccinella 7-punctata

Prey	No. of replicates	Mean time before 1st capture (min.)	Mean no. of prey encountered	Mean time spent feeding (min.)	Wet weight eaten (%)	Dry weight eaten (%)
		(*a*) 1st-instar larvae				
Myzus persicae	10	1·4	1·1	101·3	61·5	52·3
Aphis fabae	10	2·3	1·1	233·9	63·8	46·1
Acyrthosiphon pisum	10	2·3	1·1	82·4	90·8	80·7
Megoura viciae	10	3·8	2·5	422·8	58·6	33·8
		(*b*) 4th-instar larvae				
Myzus persicae	10	1·6	1·5	3·3	100·0	100·0
Aphis fabae	9	1·2	1·0	3·2	100·0	100·0
Acyrthosiphon pisum	11	1·6	1·3	5·0	96·4	93·6
Megoura viciae	12	0·5	1·2	4·6	94·2	90·3

Adalia bipunctata: *4th instar*

Fourth-instar larvae encountered as many aphids before making a capture as did 1st-instar larvae, but the time before first capture was generally less because the larger larvae moved much more quickly (Table 4*b*). The larvae spent a similar time feeding on and ate similar proportions of *M. persicae* and *A. pisum*. Larvae took about five times longer on *A. fabae*, and as in previous experiments ate less of each aphid. The 4th-instar larva of *A. bipunctata* accepted *M. viciae* readily, but after about 4 min. feeding suddenly rejected its prey and vomited, suggesting that this time was needed for the toxin to act.

Coccinella 7-punctata: *1st instar*

These larvae, slightly larger than the 1st instar of *A. bipunctata*, were more efficient at capturing their prey (Table 5*a*). The first aphid encountered was usually successfully captured. Similar times were spent feeding on *M. persicae* and *A. pisum*, as by *A. bipunctata*. The larvae also took much longer to feed on *A. fabae*, but more of the aphid was eaten by *C. 7-punctata* than by *A. bipunctata*. Similar amounts of *M. persicae* and *A. fabae* were eaten, but the larvae ate much more of *A. pisum*, which seemed to be the most suitable aphid for 1st-instar *C. 7-punctata*. Larvae took over five times as long to feed on an *M. viciae* as on an *A. pisum*, and consumed much less of it (Table 5*a*).

Coccinella 7-punctata: *4th instar*

Fourth-instar *C. 7-punctata* appeared to be very efficient predators (Table 5*b*). They quickly captured and ate all the aphid species. Larvae feeding on *M. persicae* and *A. fabae* consumed their aphids completely. One or two legs of *A. pisum* were invariably left, and usually most of the cuticle of *M. viciae*. It is concluded that:

(1) *C. 7-punctata* is a more efficient predator than *A. bipunctata* on the species of aphid used in the experiments, perhaps because it is larger.

(2) The 4th-instar larva of both species is a much more efficient predator than the 1st instar. The relative sizes of the predator and its prey should, however, be considered. The aphids presented to 1st-instar larvae were relatively much larger than those presented to 4th-instar larvae. The 1st-instar larvae might have fared better on aphids weighing less than 0·3 mg. Nevertheless, observations of the behaviour of 1st-instar larvae under natural conditions suggest that very small aphids are not necessarily selected as prey. Of five 1st-instar larvae of *C. 7-punctata* released on *Vicia faba* infested with *A. pisum*, two first caught large late-instar aphids: two caught 2nd instars of about the size of those used in the feeding experiments, and only one caught a 1st instar.

(3) A larva which spends longer than normal feeding on an aphid generally consumes relatively less of the aphid. This is associated with the aphid species being unsuitable for larval development, e.g. *A. fabae* for *A. bipunctata*.

(4) The effect of an unsuitable food is more pronounced on the 1st than on the 4th instar.

DISCUSSION

These results demonstrate a considerable variation in the suitability of aphid species as food for *A. bipunctata* and *C. 7-punctata*. For example, *M. persicae*, *A. circumflexum*, *A. pisum* and *M. evansi* seem to satisfy all the nutritional requirements for development of *A. bipunctata* larvae. Other aphids (*A. fabae*, *A. sambuci*, *B. brassicae*) are relatively unsuitable, and *M. viciae* is toxic. Different aphid species may similarly affect adult fecundity. The two coccinellid species differ in their range of suitable prey. For example, *M. viciae* is toxic to *A. bipunctata* but only slightly unsuitable for larval development of *C. 7-punctata; A. fabae* is relatively unsuitable as food for larvae and adults of *A. bipunctata* but seems to satisfy all the nutritional requirements of *C. 7-punctata.* Thus this evidence from a few of their potential prey species shows that the two coccinellids have some specificity in the nutritional requirements.

A. fabae and *A. sambuci* were found to be relatively unsuitable food for *A. bipunctata,* although they are naturally common prey of this coccinellid. The longer development time and greater mortality of the larvae may be relatively unimportant, especially as *A. fabae* as larval food does not seem to affect adult fecundity; but the much reduced fecundity of adult *A. bipunctata* fed on *A. fabae* is probably more significant. *A. fabae* is an 'essential' food of *A. bipunctata* (Hodek 1962), but it is one which does not allow the coccinellid to realize its full reproductive potential.

Reasons for the unsuitability or toxicity of certain aphid species are difficult to determine. The unsuitability of *A. fabae* to larvae of *A. bipunctata* has already been discussed. In this case two factors appear to be concerned: difficulty in ingesting food once the prey is captured, and low nutritive value. The two may be related; the nutritive value may be low because some essential nutrient is left in the uningested part of the prey. In other instances a third factor may be involved—difficulty in capturing the prey (e.g. Dixon, 1958). This is least likely for adults and 4th-instar larvae, which are generally efficient at capturing and eating prey; for them the nutritive value of the food is likely to be the most important factor influencing suitability. Difficulty in catching and eating the food may be relatively more important for younger larvae.

The aphid host plant may affect the value of the aphid as food. However, *Aphis fabae* had the same effect on *larvae* of *A. bipunctata* whether it was reared on *V. faba* or *E. europeaus,* and *M. persicae* reared on *B. oleracea* and on *V. faba* were equally suitable for *C. 7-punctata* larvae. It has been postulated that aphids containing toxic substances obtain them from the host plant. Hodek (1956, 1957) suggests that the adverse effect of *A. sambuci* on *C. 7-punctata* may be due to the presence of the glycoside sambunigrin obtained by the aphids from the elder (*Sambucus nigra*), which could be broken down by the coccinellid to hydrocyanic acid. The toxicity of *M. viciae* to *A. bipunctata* (and to *A. 10-punctata,* Dixon 1958) could also be due to a substance obtained from the host plant (Dixon, Martin-Smith & Subramanian 1965).

The possible ecological significance of some of the results of this work is discussed in a second paper (Blackman, 1966), which deals with the selection behaviour of the larvae and adults of *A. bipunctata* and *C. 7-punctata.*

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REFERENCES

BANKS, C. J. (1957). The behaviour of individual coccinellid larvae on plants. *Br. J. Anim. Behav.* **5**, 12–24.

BLACKMAN, R. L. (1965). Studies on specificity in Coccinellidae. *Ann. appl. Biol.* **56**, 336–8.

BLACKMAN, R. L. (1967). Selection of aphid prey by *Adalia bipunctata* L. and *Coccinella 7-punctata* L. *Ann. appl. Biol.* (In the Press.)

DIXON, A. F. G. (1958). The escape responses shown by certain aphids in the presence of the coccinellid *Adalia 10-punctata* L. *Trans. R. ent. Soc. London.* **110**, 318–334.

DIXON, A. F. G., MARTIN-SMITH, M. & SUBRAMANIAN, G. (1965). Constituents of *Megoura vicia* Buckt. *J. chem. Soc.* pp. 1562–4.

HAWKES, O. A. M. (1920). Observations on the life-history, biology and genetics of the lady-bird beetle, *Adalia bipunctata*. *Proc. zool. Soc. Lond.* pp. 475–90.

HODEK, I. (1956). The influence of *Aphis sambuci* L. as prey of the ladybird beetle *Coccinella 7-punctata* L. *Vest. čsl. zeměd. Mus.* **20**, 62–74.

HODEK, I. (1957). The influence of *Aphis sambuci* L. as food for *Coccinella 7-punctata* L. II. *Čas. čsl. Spol. ent.* **54**, 10–17.

HODEK, I. (1959). The influence of various aphid species as food for the ladybirds *Coccinella 7-punctata* L. and *Adalia bipunctata* L. In *The Ontogeny of Insects*, pp. 314–16. Prague.

HODEK, I. (1962). Essential and alternative food in insects. *XIth Int. Congr. Ent.* (Vienna), 1960, **2**, 698–99.

KADDOU, I. K. (1960). The feeding behaviour of *Hippodamia quinguesignata* Kirby larvae. *Univ. Calif. Publs Ent.* no. 16, pp. 181–232.

SCHILDER, F. & SCHILDER, M. (1928). Die Nahrung der Coccinelliden und ihr Beziehung zur Verwandtschaft der Arten. *Arb. biol. BundAnst. Land- u. Forstw.* **16**, 213–81.