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Selection of aphid prey by *Adalia bipunctata* L. and *Coccinella 7-punctata* L.

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SUMMARY

Larvae and adults of *Adalia bipunctata* L. and *Coccinella 7-punctata* L. seemed unable to detect and avoid feeding on unsuitable or toxic aphids, e.g. larvae of *A. bipunctata* fed on the highly toxic *Megoura viciae*, even when given the choice of a suitable aphid. Apparent preferences were not always for the most suitable food.

Field cage experiments demonstrated the preference of adult *A. bipunctata* and *C. 7-punctata* for different habitats, the former ovipositing at the shrub level (4 ft.) and the latter feeding and ovipositing on plants near ground level.

INTRODUCTION

The development and fecundity of *Adalia bipunctata* L. and *Coccinella 7-punctata* L. vary considerably according to the species of aphid food (Blackman, 1967), but there is very little evidence that aphidophagous coccinellids are selective in their choice of prey. Hawkes (1920) claims that the aphids *Macrosiphum aconitum* van der Goot, *Hyalopterus arundinis* F. and *Aphis fabae* Scop. are unacceptable to *A. bipunctata.* Smee (1922) never observed *A. bipunctata* feeding on *A. fabae* in the field, but Banks (1955) found that *A. bipunctata* was the commonest ladybird species associated with *A. fabae* on *Vicia faba* L., and the writer has observed many *A. bipunctata* feeding on *A. fabae*, both on *V. faba* and on *Euonymus europaeus* L. Campbell's (1926) statement, that ladybirds do not attack *Acyrthosiphon pisum* Harris as readily as other species of aphid, also appears to be unfounded.

In the field, the degree to which a coccinellid feeds on a particular species of aphid depends on other factors besides the extent to which it selects its food, e.g. the relative abundance of the aphid and the extent to which the habitats and life-histories of predator and prey coincide. The following experiments were done to find out whether selection occurred in conditions where the habitat and other factors were excluded.

MATERIALS AND METHODS

Predators were given a choice of aphids by confining them singly in 1 in. diam by $\frac{5}{8}$ in. high Perspex cylindrical cells. Each cell was placed on a bean leaf on wet filter paper. The lid of the cell was of bolting silk stretched across a $1\frac{5}{8}$ in. diameter gal-

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vanized iron ring, the weight of which pressed the lower rim of the Perspex cylinder on to the leaf.

To compare the attractiveness of two species of aphid, equal numbers of similar-sized early-instar nymphs of the two species were put into each cell, sufficient to provide ample food for 24 hr. Every day the survivors of each species were counted, the cells cleaned and fresh aphids added. Only aphids which behaved similarly under the experimental conditions were compared, e.g. *A. pisum* with *Megoura viciae* Buckt. and *A. fabae* with *Myzus persicae* Sulz. This minimized the effects of aphid behaviour and size on selection by the predator. All experiments were done at a constant temperature of 20° C. and with a 16 hr. photoperiod.

RESULTS

Food selection by the larvae

A. fabae is inferior to *M. persicae* as a food for larval *A. bipunctata* (Blackman, 1967). Larvae reared on a mixture of equal numbers of *M. persicae* and *A. fabae* (Fig. 1) developed in 12·2 days, compared with 13·0 days on *A. fabae* and 10·4 days on *M. persicae* alone (Blackman, 1965). Only the 4th instar showed a significant (5 %) preference for the more suitable aphid (Table 1).

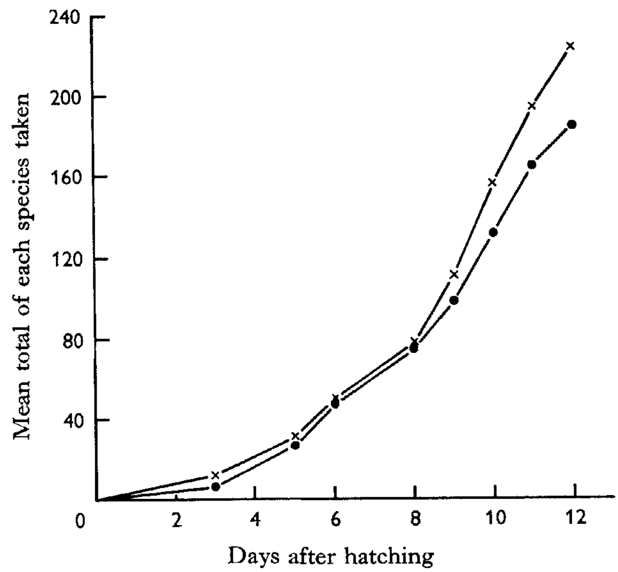

Fig. 1. Selection behaviour by larvae of *A. bipunctata* given a mixture of equal numbers of *A. fabae* and *M. persicae*. Prey: ●, *Aphis fabae*; ×, *Myzus persicae*.

To find whether larvae could be conditioned to select one species of aphid from a mixture, by previous feeding on that species alone, two groups of twelve larvae were reared to 4th instar, one on *M. persicae* and the other on *A. fabae*. After moulting from the 3rd instar all larvae were given a mixture of equal numbers of each aphid, and the numbers of each aphid eaten were recorded for two successive days. Table 1 shows that on the first day the larvae were uninfluenced by previous diet, but on the second day both groups ate significantly more *M. persicae*.

In another experiment larvae of *C. 7-punctata* were given a mixture of equal numbers of *A. pisum* and *M. viciae*, of which the latter is less suitable (Blackman, 1967). As with *A. bipunctata*, only the older larvae showed a tendency to select (Fig. 2), but they chose the less suitable aphid.

Table 1. *Effect of previous diet on selection behaviour of 4th-instar larvae of* Adalia bipunctata *given a mixture of equal numbers of* Myzus persicae *and* Aphis fabae.

Treatment	Percentage of aphids eaten which were *A. fabae*		
	1st day	2nd day	3rd day
Larvae reared to 4th instar on a 50/50 mixture	40·3	43·2	44·3
Larvae reared to 4th instar on *M. persicae*	43·7	37·5	—
Larvae reared to 4th instar on *A. fabae*	39·6	31·2	—

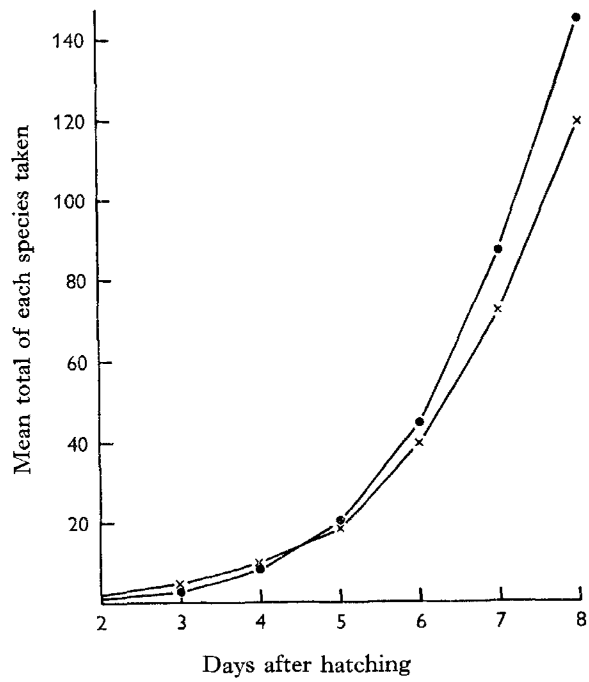

Fig. 2. Selection behaviour by larvae of *C. 7-punctata* given a mixture of equal numbers of *A. pisum* and *M. viciae*. ●, *M. viciae*; ×, *A. pisum*.

Observations were then made on *C. 7-punctata* larvae given four species of immobilized prey, *A. pisum*, *M. persicae*, *A. fabae* and *M. viciae*. Three individuals of each species, all of about the same size, were cemented to the floor of a 3 in. diameter

Petri dish, in alternate positions in a 2 in. diameter circle. The predator, kept without food overnight, was placed in the centre of the circle, and observed until it started feeding on an aphid. If it left the circle without encountering an aphid it was replaced in the centre. An encounter followed by feeding for 10 min. by a 1st-instar predator, or for 2 min. by a 4th instar was counted as an acceptance. A prey touched with the mouthparts but abandoned before the critical time was counted as a rejection.

Table 2. *Behaviour of* Coccinella 7-punctata *with immobilized prey*

Species of aphid	No. of encounters	No. of acceptances	No. of rejections
(*a*) 1st-instar larvae			
Myzus persicae	28	21	7
Aphis fabae	28	23	5
Acyrthosiphon pisum	28	26	2
Megoura viciae	25	22	3
(*b*) 4th-instar larvae			
Myzus persicae	30	19	11
Aphis fabae	36	32	4
Acyrthosiphon pisum	37	30	7
Megoura viciae	39	29	10

The results in Table 2 indicate that when presented with immobilized prey, neither 1st- nor 4th-instar larvae of *C. 7-punctata* preferred or disliked any of the four aphid species. Most of the aphids encountered were accepted.

Experiments so far have compared the effects of aphid species all of which are adequate as larval food. To test the ability of larvae of *A. bipunctata* to avoid feeding on *M. viciae*, which is highly toxic to them (Blackman, 1967), five groups of twelve newly hatched 1st-instar larvae were placed in separate rearing cells. One group was given each of the following treatments: (1) starved; (2) fed on a suitable aphid, *A. pisum*; (3) fed on *M. viciae*; (4) fed on a mixture of equal numbers of *M. viciae*, and *A. pisum*; (5) fed on a mixture of *M. viciae* and *A. pisum* in the proportions of 1:9 respectively.

Each day the numbers of predators and of each species of aphid surviving were recorded, the cells were cleaned and fresh aphids provided in the same proportions as before. Figure 3 shows that two-thirds of the larvae fed on *A. pisum* survived and pupated after 10–11 days. All larvae fed on *M. viciae* alone were dead on the second day, before those which were starved. This confirms the quick action of a toxin in *M. viciae* (Blackman, 1967). Five of the larvae given a mixture of equal numbers of *M. viciae* and *A. pisum* survived to the 2nd instar, and one attained the 3rd instar but died on the 10th day after killing a total of fourteen *A. pisum* and eleven *M. viciae*.

All of the larvae given aphids in the proportion of nine *A. pisum*: one *M. viciae* died before pupating, although seven reached the 4th instar and two survived for 16 days; the seven larvae surviving to the 4th instar killed an average of 7·3 *M. viciae* and 86·9 *A. pisum*. The longer a larvae survived, the less susceptible it was to *M. viciae*. Fourth-instar larvae of *A. bipunctata* reject *M. viciae* suddenly after about 4 min. feeding (Blackman, 1967).

This experiment shows that *A. bipunctata* larvae do not avoid feeding on *M. viciae*, but seemingly they select more of the suitable aphid. Thus, larvae given equal numbers of *M. viciae* and *A. pisum* took an average of 6·8 *A. pisum* and 2·4 *M. viciae*.

In a further experiment two groups of twelve *A. bipunctata* were reared up to the second day of the 4th instar on *A. pisum*. One group was then fed on *M. viciae*, while the other was starved. Larvae fed on *M. viciae* survived 23–191 hr. with a mean survival time of 100·4 hr. None pupated. Seven of the twelve starved larvae pupated after 71–120 hr., with a mean time to pupation of 85·6 hr., while the other five died before pupating but survived longer than the larvae fed on *M. viciae* (167–240 hr., mean survival time 196·2 hr.).

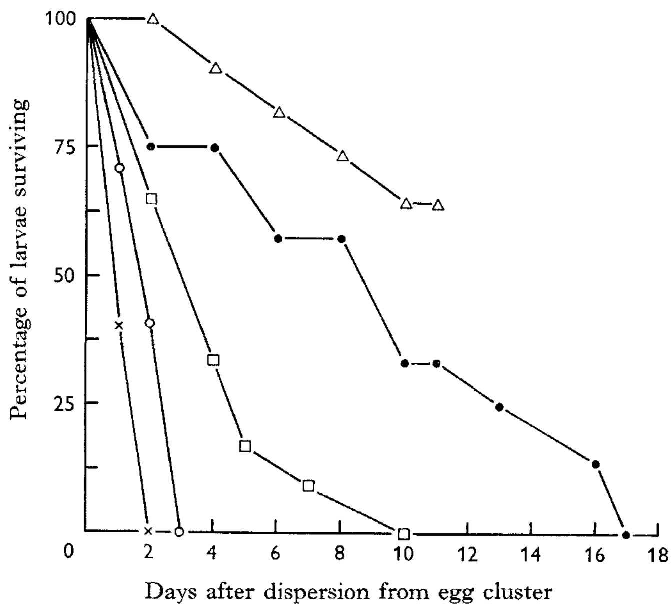

Fig. 3. Toxicity of *Megoura viciae* to larvae of *Adalia bipunctata*. Diet of larvae: △, *Acyrthosiphon pisum* alone; ×, *Megoura viciae* alone; ○, starved; □, *M. viciae*/*A. pisum* 50/50; ●, *M. viciae*/*A. pisum* 10/90.

Food selection by the adult

Adult coccinellids actively disperse in the field and therefore must contact many more species of potential prey than do the larvae. The ability of the adult to choose suitable food is therefore important, especially as the oviposition site and hence the food of the larvae are likely to be related directly to a food supply selected by the adult.

Twenty-four 2-3-day-old adult *A. bipunctata*, reared as larvae on *A. pisum* and previously unfed as adults, were confined singly in cells and given equal numbers of large nymphs of *M. persicae* and *A. fabae*. Table 3 shows that adults of *A. bipunctata* ate more of the more suitable aphid, *M. persicae*.

A similar experiment was done with both *A. bipunctata* and *C.7- punctata*, reared as larvae on *M. persicae*, and when adult given mixtures of *A. pisum* and *M. viciae*. Few

M. viciae were available, so the numbers of each species presented were not equal (i.e. two *A. pisum*: one *M. viciae* on the second day after emergence and three *A. pisum*: one *M. viciae* on the third day). Table 4*a* shows that adults of *A. bipunctata* were not able to distinguish between the toxic and the suitable aphid. Adults of *C. 7-punctata* (Table 4*b*) however apparently preferred the less suitable *M. viciae*. This conforms with the results using the 4th-instar larva of *C. 7-punctata* (Fig. 2).

Table 3. Selection by adult Adalia bipunctata *given a mixture of equal numbers of* Myzus persicae *and* Aphis fabae.

	Percentage of each species taken		
	Myzus persicae	*Aphis fabae*	S.D.
2nd day after emergence	69·8	30·2	±14·1
3rd day after emergence	65·2	34·8	±16·0

Selection of oviposition site

The eggs of aphidophagous coccinellids are not necessarily laid close to colonies of prey (Banks, 1956). Dixon (1959) records an association between eggs batches of *Adalia 10-punctata* L. and colonies of the aphid *Eucallipterus tiliae* L., but considers that the adults oviposited close to aphids because they were less active through being well-fed, and consequently remained in the vicinity of their own food supply.

Table 4. *Selection from a mixture of* Acyrthosiphon pisum *and* Megoura viciae

	Percentage taken of those presented		
	A. pisum	*M. viciae*	
	(*a*) By adult *A. bipunctata*		
2nd day after emergence	15·6 ± 9·5	9·2 ± 10·2	No significant difference between the two species
3rd day after emergence	29·5 ± 5·7	33·3 ± 14·8	
	(*b*) By adult *C. 7-punctata*		
2nd day after emergence	7·3 ± 5·4	31·7 ± 14·4	Significant difference between the two species
3rd day after emergence	41·7 ± 25·3	82·5 ± 24·0	

There is evidence of habitat preferences by coccinellid species. Hodek, Stary & Stys (1962), for example, record that in Czechoslovakia *C. 7-punctata* and *C. 5-punctata* are typical of fields, whereas *A. bipunctata* is rare in fields but common on trees and shrubs. Iperti (1965) shows that in Southern France seven species of aphidophagous Coccinellidae occur at different heights and in different types of vegetation, especially in the larval stage. This indicates oviposition site selection by the adult female.

This aspect of oviposition behaviour was studied with adults of *A. bipunctata* and *C. 7-punctata*, given a choice of oviposition sites at different height levels in 5 ft. high × 4 ft. × 3 ft. field cages. Broad bean plants (*V. faba*) in pots were suspended by wires at heights of 4 ft., and 2 ft. 6 in., and others were placed on the gravel floor of the cage, four pots at each height. The plants were infested with *A. pisum* and renewed every 2 weeks. In August 1964, fifteen pairs of young adults of each species of coccinellid were put in the same field cage. The numbers of eggs laid on the plants and plant pots at each level were recorded on alternate days. Eggs laid on the cage walls were disregarded. In practice it was found difficult to distinguish egg batches of the two species, so they were identified from the larvae hatched in the laboratory. The experiment was repeated in July/August 1965 using a separate field cage for each species. In both years the experiment was ended when oviposition ceased.

Table 5. *Selection of oviposition site in relation to height in a field cage by* Adalia bipunctata *and* Coccinella 7-punctata

	A. bipunctata			*C. 7-punctata*		
Level	Total no. of eggs	Total no. of egg batches	Total no. of adults observed	Total no. of eggs	Total no. of egg batches	Total no. of adults observed
			1964			
High (4 ft.)	312	27	15	—	—	1
Medium ($2\frac{1}{2}$ ft.)	123	11	13	5	1	1
Low (6 in.)	113	8	10	89	8	15
			1965			
High (4 ft.)	426	32	17	—	—	1
Medium ($2\frac{1}{2}$ ft.)	140	13	7	11	1	1
Low (6 in.)	101	9	12	40	3	26

Few eggs were recorded for *C. 7-punctata*; this species tended to oviposit on the mesh and wooden framework of the cage rather than on the plants. Nevertheless, the results (Table 5), which agree closely for the 2 years, confirm Iperti's (1965) field observations that *A. bipunctata* prefers to lay at a higher level than *C. 7-punctata*. Adults of *A. bipunctata* appeared to move freely throughout the available height range, in spite of their oviposition preference, but adults of *C. 7-punctata* chose the ground-level plants and did not feed on aphids at higher levels, although they were often seen on the roof of the cage in sunny weather.

DISCUSSION

The results indicate that *A. bipunctata* and *C. 7-punctata* cannot detect and avoid unsuitable or toxic species of aphid. Slight preferences were not always for the more suitable aphid; C. *7-punctata*, for instance, ate more *M. viciae* than *A. pisum*. Larvae of *A. bipunctata* seemed to prefer *A. pisum* when given this aphid with *M. viciae*, but could not avoid feeding on the toxic *M. viciae* and eventually died.

Results of laboratory choice experiments must be interpreted with caution. It could be argued that in the laboratory a coccinellid provided with an excess of food is most likely to demonstrate any preference it may have for one prey over another. Therefore laboratory work would emphasize any ability to select, whereas only marked preference for one aphid or a strong avoidance reaction to another would be important in the field where food is often scarce. However, a coccinellid can more easily avoid an unsuitable aphid in the field than in confined conditions in a laboratory. The adult finding an aphid colony which is unsatisfactory may eat a few aphids and then become restless and leave. This could continue until it found a more suitable species on which it would stay and reproduce. Adults of *A. bipunctata*, for example, which in the laboratory seemed unable to distinguish *M. viciae* from *A. pisum*, may in this way avoid prolonged contact with *M. viciae* in the field. The preference of *A. bipunctata* for higher levels of vegetation may often keep it away from *M. viciae*, but they sometimes occur in the some habitat, as in July 1965 at Silwood Park when numerous adults and larvae of *A. bipunctata* were found on *A. fabae*-infested field beans, but none on neighbouring bean plants infested with *M. viciae*.

The distribution of adult coccinellids will depend partly on the location and abundance of food and partly on their specific habitat preferences. Thus if there is adequate food at all levels of vegetation, *A. bipunctata* and *C. 7-punctata* will show a tendency to feed, and especially to lay their eggs, at different levels. The preference seems to be related to height above ground as well as to particular types of vegetation or microclimate. This was apparent when similar oviposition sites were presented at different heights in a field cage.

Within their preferred habitats the two species will encounter aphids which vary in value as food (Blackman, 1967), some satisfying all their nutritional requirements, but others being either unsuitable or lethal. It seems unlikely that unsuitable aphids are actively avoided, and it can happen that a relatively unsuitable species of aphid is a common prey for both adults and larvae (e.g. *A. fabae* for *A. bipunctata*, Blackman, 1967).

Aphidophagous coccinellids in general are able to utilize the largely unpredictable outbreaks of aphids as they arise, laying eggs and developing larvae when aphid food is plentiful. Specific differences in choice of habitat and range of suitable aphid prey have perhaps evolved to minimize interspecific competition.

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REFERENCES

BANKS, C. J. (1955). An ecological study of Coccinellidae associated with *Aphis fabae* Scop. on *Vicia faba*. *Bull ent. Res.* **46**, 561–87.

BANKS, C. J. (1956). The distribution of coccinellid egg batches and larvae in relation to numbers of *Aphis fabae* Scop. on *Vicia faba*. *Bull ent. Res.* **47**, 47–56.

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

BLACKMAN, R. L. (1967). The effects of different aphid foods on *Adalia bipunctata* L. and *Coccinella 7-punctata* L. *Ann. appl. biol.* (in the Press).

CAMPBELL, R. E. (1926). The pea aphis in California. *J. agric. Res.* **32**, 861–81.

DIXON, A. F. G. (1959). An experimental study of the searching behaviour of the predatory coccinellid beetle *Adalia decempunctata* L. *J. Anim. Ecol.* **28**, 259–81.

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

HODEK, I., STARY, P. & STYS, P. (1962). The natural-enemy complex of *Aphis fabae* and its effectiveness in control. *XI Int. Congr. Ent.* (*Vienna*) 1960, **2**, 747–9.

IPERTI, G. (1965). Contribution a l'étude de la spécificité chez les principales Coccinelles aphidiphages des Alpes-Maritimes et des Basses-Alpes. *Entomophaga* **10**, 159–78

SMEE, C. (1922). British ladybird beetles. Their control of aphids. *Fruitgrower* **53**, 675, 717, 759.