Studies on specificity in Coccinellidae

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New approaches to pest control involving biological methods are frequently hampered by lack of fundamental knowledge. This applies especially to predation. The exact nature of the relationship between predatory insects and their prey needs study, even for comparatively well-known predators like the Coccinellidae.

The work outlined in this paper forms part of an investigation into the suitability of various aphid species as food for *Adalia bipunctata* L. and *Coccinella septempunctata* L., perhaps the commonest ladybird species found in this country.

Suitability of different aphid species as food for Adalia bipunctata *L.*

A comparison of the development of *A. bipunctata* larvae fed on six different aphid species is given in Table 1. All experiments were done in a constant temperature room at 20° C. illuminated for 16/24 hr.

Table 1. *Development of* Adalia bipunctata *larvae on different aphids*

Species of aphid used as food	Mean time for development (days)	Mortality during larval development (%)	Mean weight of adult at emergence (mg.)
Myzus persicae	10·4	17·8	11·8
Aulacorthum circumflexum	9·5	16·7	11·9
Acyrthosiphon pisum	10·8	13·9	12·6
Microlophium evansi	10·6	9·1	12·4
Aphis fabae	13·0	27·6	7·9
Aphis sambuci	13·4	25·0	8·0

It can be seen that the time required for larval development on *Aphis fabae* Scop. and *A. sambuci* L. is greater, the mortality is higher, the weight attained at pupation, and hence the weight of the adult at emergence, is lower. The other four species all give a uniformly rapid developmental rate and are clearly all suitable foods for larvae of *Adalia bipunctata*.

About 80 % of the increase in weight during larval development takes place in the fourth instar. Fourth-instar larvae fed on *Myzus persicae* Sulz. grow far more quickly than those fed on *Aphis fabae*, and this was found to be attributable to two factors: (*a*) a difference in growth efficiency, i.e. the increase in weight of the larva per unit of dry weight of aphid ingested, and (*b*) a difference in the proportion of each aphid attacked which is actually ingested. Thus the larva feeding on *A. fabae* consumes less of each aphid that it captures, and the material which it does consume is less nutritious than that obtained from *Myzus persicae*. There is also a noticeable difference in the feeding behaviour of *Adalia bipunctata* larvae sucking *Aphis fabae*. The active pumping of digestive fluids into and out of the aphid body, which is a feature of the feeding behaviour of Coccinellid larvae, seems to be lacking when the prey is *A. fabae*.

A comparison of the fecundity of *Adalia bipunctata* fed on *Aphis fabae* and on a suitable aphid, *Myzus persicae*, shows that *Aphis fabae* is also a comparatively unsuitable food for the adult. Female beetles fed from emergence on *A. fabae* laid much less than half the mean total number of fertile eggs laid by those feeding on *Myzus persicae*. However, the type of food given to the larva did not affect the fecundity of the adult. For example, female beetles fed on *M. persicae* but reared as larvae on *Aphis fabae* were as fecund as those from larvae reared on *Myzus persicae*.

Megoura viciae Buckt. appears to be toxic to *Adalia bipunctata*. It is lethal to all larval stages and to the adult. Neither larva nor adult has the ability to avoid feeding on this species when it is presented mixed with a suitable food. Even when a group of larvae were fed on a mixture of *Megoura viciae* and *Acyrthosiphon pisum* Harris in the ratio of one to nine, none of the larvae reached the pupal stage. First-instar larvae fed with *Megoura viciae* alone were all dead within 2 days, quicker than if starved.

Suitability of different aphid species as food for Coccinella septempunctata *L.*

Results of experiments with *C. septempunctata* were different from those with *Adalia bipunctata*. Larvae of *C. septempunctata* were able to develop on *Aphis fabae* as rapidly as on any other species of aphid (Table 2). They were also able to develop on *Megoura viciae*, although feeding on this species caused a slight increase in development time and gave a slightly smaller adult.

Table 2. *Development of* Coccinella septempunctata *larvae on different aphids*

Species of aphid used as food	Mean time for development (days)	Mortality during larval development (%)	Mean weight of adult at emergence (mg.)
Myzus persicae	13·0	12·5	36·4
Aphis fabae	13·6	9·1	36·3
Acyrthosiphon pisum	13·3	18·6	37·2
Megoura viciae	14·8	13·4	33·5

Three general conclusions can be drawn from these and other results obtained.

1. Different aphid species vary in their suitability as food for a particular Coccinellid species.

2. The same species of aphid which is unsuitable or even toxic to one species of Coccinellid may be a suitable food for another. For example, *M. viciae* is toxic to *Adalia bipunctata* larvae but is suitable for larval development of *C. septempunctata*. Conversely, Hodek (1959) found that *Aphis sambuci* was detrimental to *C. septempunctata* but would permit development of *Adalia bipunctata*. Thus there is a degree of physiological specificity which is not associated with acceptability of food, since almost all aphid species seem to be accepted irrespective of their value as food.

3. A relatively unsuitable species of aphid may be common prey of adults and larvae of a Coccinellid species. For example, *Aphis fabae* will permit completion of the life-cycle of *Adalia bipunctata*, but will not allow this species to realize its full reproductive potential. Yet in England *A. bipunctata* occurs commonly as larvae and adults feeding on *Aphis fabae*, and also on *A. sambuci*, another relatively unsuitable species, and it is likely that these two species form a large proportion of the food of the *Adalia bipunctata* population in this country.

In general, adult Coccinellids have great mobility, searching over large areas for their food. Distribution of the larvae, on the other hand, is restricted to the vicinity of the eggs from which they hatched. Thus the food and habitat of the larva are determined by the oviposition site chosen by the adult. There is evidence that the adult Coccinellid shows some degree of specificity in its choice of oviposition site, but this appears to be based primarily on habitat selection and only secondarily on the presence or abundance of aphids. When *C. septempunctata* and *Adalia bipunctata* were given a choice of oviposition sites consisting of broad-bean plants in pots suspended at different heights, *C. septempunctata* eggs were laid almost exclusively at ground level, whereas *A. bipunctata* tended to lay its eggs on plants suspended at higher levels. Iperti (1961, 1965) has recently collected data on the distribution of aphid-eating Coccinellids in the South of France, and his results substantiate the hypothesis that habitat selection is associated with height of vegetation.

It is clear that certain species of Coccinellid commonly regarded as non-specific are in fact specific to the extent that in breeding they tend to be restricted to a particular habitat, and do not succeed on all aphid species. The contribution to pest mortality made by Coccinellids might be increased if attention was concentrated on the particular species likely to be most effective as a predator on the pest in question, taking both nutritional and ecological factors into consideration. Clearly it is also necessary to study the food of Coccinellids on wild plants, in both wild and cultivated habitats, because it is in these conditions that the predator needs to be encouraged in order that adequate numbers of the right species will emigrate to crops at the right time of year.

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Pest ecology and integrated control

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The present paper is concerned with the relation of pest ecology to the problem of control, integrated or otherwise. This relation is not nearly so well appreciated as many people believe.

Let me begin by stating what is generally understood by the terms 'pest ecology' and 'integrated control'. Ecology itself is the science of relationships between living organisms and their environment, both animate and inanimate. *Pest ecology* is simply the assessment of the relation between environment and the distribution of a pest's numbers in time and space; and, of course, this assessment entails study of the various effects of environmental factors on life-history, behaviour, development, reproduction, dispersal and mortality. In the present context, control itself means the preventing of a significantly injurious level of numbers. According to the Fraser Research Committee (A.R.C. 1964*a*, p. 7), '*integrated control* of a pest is the co-ordination of all known cultural, biological, ecological and chemical methods in such a way as to obtain the maximum total benefit and especially to minimise harmful side effects that may result from exclusive use of chemical pesticides'.

I am sometimes asked the question: 'Of what use is your laborious pest ecology in the problem of control?' The implication is, of course, that it is of very little use. One way to rebut this implication is to give some examples. Of the following four examples, the first three are from our own work in the North of England.

Example 1. The sheep tick, *Ixodes ricinus* L., can be economically controlled by a combination of pasture-improvement with acaricidal treatment of farm stock, i.e. by the integration of a cultural method with a chemical method which harms neither stock nor man. This integrated control programme was derived, and could only have been derived, from a full knowledge of the tick's ecology, particularly the reasons for its numerical distribution on the ground and the facts of its numerical incidence on domestic and wild hosts. Both the ecological study and its practical applications were summarized in 1952 (Milne, 1952); and the final requisite for the control programme, namely a longer-lasting acaricidal dip, was marketed soon after.

Example 2. The garden chafer, *Phyllopertha horticola* (L.), can be economically controlled in meadows by pasture-improvement alone, and so the broadcasting of dangerous chemicals is avoided. This cultural method was derived, and could only be derived, from a thorough knowledge of the garden chafer's ecology, particularly aspects such as phenology, spatial distribution of larvae, and dispersal of adults. Full details of both the method and the confirmatory tests are now being prepared for the press.

Example 3. Our current, unfinished study of the ecology of the *Tipula oleracea* group of leatherjackets has already enabled us to forecast the trends of *T. paludosa* populations in Northumberland with considerable certainty (Milne, Laughlin & Coggins, 1965). Briefly, it is a matter of the moisture requirements of the egg and/or first-instar larva: when August/September rainfall is below 50% of normal, sharp decreases in population will certainly occur; and when rainfall at that time is normal or greater than normal, increases may usually

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