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Evaluation of some coccinellid species for the biological control of aphids in protected cropping

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SUMMARY

Four species of Coccinellidae, *Adalia bipunctata* (L.), *Coccinella septempunctata* L., *Coelomegilla maculata* de G. and *Cycloneda sanguinea* L., were compared as predators of aphids on cucumbers and chrysanthemums. In laboratory feeding tests *C. maculata* and *C. sanguinea* proved the most voracious but the former could not remain on cucumber foliage long enough to be effective. The fecundity of *C. sanguinea* was the highest of those studied and a satisfactory laboratory rearing technique has been developed for this species.

INTRODUCTION

There has recently been considerable interest in extending the scope of biological control under glass following successful control of the mite *Tetranychus urticae* Koch by the predatory mite *Phytoseiulus persimilis* Athios-Henriot in commercial-scale trials on cucumbers (Gould, Hussey & Parr, 1969). Aphids are likely to become important pests in the absence of routine pesticide applications and so a study was begun to investigate the use of aphid predators. Although chrysophid larvae seem more efficient predators than coccinellids (Sundby, 1966) and are more convenient to rear artificially, they are irritated by the glandular hairs on cucumber leaves and so are unable to remain on the foliage (Scopes, 1969). Studies on the use of coccinellids were therefore principally directed to the control of *Aphis gossypii* Glover, a potentially serious cucumber pest, whose numbers can be checked by parasites only with difficulty (I. J. Wyatt, personal communication).

Four species were chosen for comparison, either because they could be conveniently obtained or because they had been extensively studied elsewhere. *Adalia bipunctata* (L.) was obtained from *Vicia faba* in a local garden; small numbers of *Coccinella septempunctata* L. were received from Malta together with several hundred from hibernating sites in the Himalayas; while *Coelomegilla maculata* de Geer and *Cycloneda sanguinea* L. were imported from Trinidad with the kind co-operation of the Commonwealth Institute of Biological Control.

The effectiveness of an aphid predator is largely determined by its voracity. In the field, both adult and larval coccinellids feed on aphids and so both stages must be considered when evaluating the role of ladybirds; however, in glasshouses released adults tend to fly out of the vents, particularly during the pre-oviposition period. Only larvae were, therefore, considered. Their voracities were first compared in the laboratory, and the most promising species further evaluated in glasshouse trials on infested plants.

If coccinellids are to be reared and sold for use in commerce, it would be preferable to utilize a single species for a variety of purposes, thereby increasing sales outlets to set against fixed production costs. Further, if larvae are to be employed it would be important to choose a species that is both easy and cheap to mass-produce. Comparisons of adult fecundity on different diets must therefore be supplemented by studies on food consumption.

COMPARISONS BETWEEN LARVAE

Development at different temperatures

Under glass, the development of integrated control programmes has been stimulated by the occurrence of pesticide resistance in spider-mites on cucumbers and in both mites and the aphid *Myzus persicae* Sulz. on chrysanthemums (Hussey, 1968). These crops are grown at temperatures of about 25 and 15 °C respectively, so the efficiencies of coccinellid species must be compared under these conditions. There are few published determinations of the effect of temperature on the development of different species of Coccinellidae. Blackman (1965) showed that, at 20 °C, *A. bipunctata* completed its larval development in $10\cdot3 \pm 0\cdot8$ days, while the pupal period was 7·4 days. The corresponding figures for *C. septempunctata* were $13\cdot0 \pm 0\cdot7$ days and 8·0 days. Sundby (1966), on the other hand, observed the development of sixty-seven larvae under similar conditions and found that *C. septempunctata* larvae matured after 15 days and the pupae after 8·5 days. There are considerable differences between these data and those reported here (Table 1), so it is possible that some strains have different temperature responses. Neither the egg nor pupa of any species was significantly affected by the temperature range studied (Table 1). The larval development of *C. maculata* and *C. sanguinea* was longer than that of the other species at each temperature. The slow larval development was most marked in the case of *C. maculata at* 16 °C.

Theoretically there could be an advantage in employing species with a slow larval development in order to maintain predators on the plants as long as possible. However, all the species responded similarly to the range of temperatures tested so that rates of larval development alone cannot identify a suitable species for use in glasshouses.

Voracity

It is difficult to obtain reliable figures for the total number of aphids consumed during the larval life of a coccinellid, because there is a difference between the minimum number required for the predator larva to mature and the number consumed from a continuous abundance of food. This basic variable largely accounts for discrepancies between figures quoted from early literature which, according to Hodek (1957), range from 100 to 1930. Iperti (1966) compared the daily intake of *M. persicae* by five different coccinellid species and concluded that there was little difference between them. From his data and the known rate of development of predator larvae at 25 °C, the total aphid consumption during the life of *A. bipunctata*

Table 1. *Development of coccinellid species at different temperatures*

	Species									
	Adalia bipunctata			*Coleomegilla maculata*			*Cycloneda sanguinea*			*Coccinella septempunctata*
Temperature (°C)	24°	21°	16°	24°	21°	16°	24°	21°	16°	21°
	(Mean development period—days)									
Egg	2	3	3	2	3	3	2	3 ± 0·5	3 ± 1	4 ± 1
Larva	9 ± 2	13 ± 1	15 ± 2	15 ± 2	17 ± 2	40 ± 3	15 ± 2	16 ± 5	25 ± 7	13 ± 1
Pupa	5	5	6 ± 1	5 ± 0·5	5 ± 0·5	5 ± 0·5	5 ± 0·5	6 ± 1	6 ± 1	7 ± 1
Total	16 ± 2	21 ± 1	24 ± 3	22 ± 3	25 ± 3	48 ± 4	22 ± 2	25 ± 6	34 ± 9	24 ± 3

Table 2. *Number of aphids consumed during the larval life of four coccinellid species at 21 ± 3 °C*

	Mean number of aphids eaten (± S.E.)		
	Myzus persicae	*Aphis gossypii*	*Acyrthosiphon pisum*
Adalia bipunctata	206 ± 10 (12)*	242 ± 10 (8)	—
Coleomegilla maculata	272 ± 15 (12)	486 ± 18 (6)	—
Cycloneda sanguinea	206 ± 20 (12)	276 ± 6 (10)	202 ± 7 (20)
Coccinella septempunctata	173 ± 14 (6)	—	—

* Number of observations in parentheses

larvae can be calculated to be 243. This estimate compares with 206 in our work (Table 2), and 252 obtained by Clausen (1916) when the larvae fed on *Macrosiphum rosae*. Further confirmation of our data is provided by Szumkowski (1955), who found that *C. maculata* consumed 449 *A. gossypii* compared with our 486 (Table 2). Sundby (1966), however, found that *C. septempunctata* consumed 400 aphids at 20 °C, which is more than twice the figure we obtained.

Table 3. *Effect of temperature on consumption of aphids by coccinellid larvae*

Mean number of *Myzus persicae* eaten (±S.E.)

Temperature (°C)	24°	21°	16°
Coleomegilla maculata	359±25 (13)	449±19 (12)	652±23 (4)
Cycloneda sanguinea	205±12 (13)	292±11 (12)	320±19 (13)

However, valid comparisons can only be made under identical conditions. In the present experiments larvae were isolated in artificially lit vials, at constant temperature, directly after emergence from the egg. Aphids were offered on small pieces of leaf-tissue kept turgid on damp filter-paper. Five large nymphal or adult aphids were introduced daily during the first larval instar. From the second instar onwards the number of aphids offered was increased so that there was a permanent excess of food. *C. maculata* proved to be significantly more voracious than the other two (Table 2), so confirming the conclusion of Clausen (1916). Both *C. maculata* and *C. sanguinea* ate more aphids at lower temperatures than high (Table 3), probably because the fourth stadium was extended. This effect, at unknown but different temperatures, is also evident in Clausen's data (1916) for *C. sanguinea.* It occurs despite the fact that, as the temperature rises, individual larvae eat more aphids daily, for they do not live so long. For instance, Dunn (1952) demonstrated that while two pea aphids were eaten daily by *C. septempunctata* at 10 °C, consumption rose to eleven per day at 21°C. Not all species respond to lower temperatures by eating more aphids, for Sundby (1966) found almost no difference in the total food intake of *C. septempunctata* at 16° and 21°C.

From the foregoing tests, *C. maculata* appears the most voracious species and has the additional advantage that its voracity is dramatically increased at chrysanthemum-growing temperatures (15–16 °C).

Aphid control on plants

Difficulty was experienced in rearing adequate numbers of *C. septempunctata*, so only three species were compared as aphid predators in experiments on chrysanthemums and cucumbers.

Chrysanthemums. Cuttings of the cultivar BGA Tuneful were grown in twelve pots (four cuttings each) and infested with *M. persicae.* When the total number of aphids had reached about 1000 per pot, ten 2nd-instar coccinellid larvae were introduced to each. A week later each coccinellid species had eliminated all but a few aphids (Table 4).

A larger experiment was then done with *C. sanguinea* larvae on twenty pots, each containing four Tuneful cuttings. Second-instar coccinellid larvae were released at a rate of one larva to twenty aphids when about 1000 aphids were present on each pot. After 14 days only about twenty aphids were left on each pot. This effective predator–host ratio confirmed that found by Dunn (1951) in his field studies on pea aphid control by *Coccinella septempunctata*.

Table 4. *Comparison of efficiency of three species of coccinellid larvae against* Myzus persicae *on chrysanthemums*

Mean number of aphids per plant

	At introduction of coccinellids	After 7 days
Control	966	2025
Adalia bipunctata	996	45
Coleomegilla maculata	1034	68
Cycloneda sanguinea	952	13

Table 5. *Comparison of efficiency of three species of coccinellid larvae against* A. gossypii *on cucumbers*

Mean number of aphids per plant

	At introduction of coccinellids	After 11 days
Control	880	27,550
Adalia bipunctata	949	17,625
Coleomegilla maculata	956	37,875
Cycloneda sanguinea	953	13,650

Cucumbers. Cucumbers were grown to the five-leaf stage in pots at 21 °C before infestation with *A. gossypii*. When about 1000 aphids were present on each of the six plants of each treatment, coccinellid larvae were released at a ratio of one larva to fifty aphids. *C. maculata* had no effect on the aphids (Table 5) because the larvae were irritated by the glandular hairs and soon fell from the leaves.

A further test was done with *C. sanguinea* by infesting twenty-four plants with aphids and releasing larvae on to three plants at a time on successive days, so that the same predatory potential was tested against increasing aphid numbers (Fig. 1). Complete control was achieved where ten coccinellids were released against up to 200 aphids, and even when 400 aphids were present very few remained.

COMPARISONS BETWEEN ADULTS

As indicated earlier, many released adults flew out of the glasshouse, but, when confined on plants in cages, they suppressed aphid population growth (Table 6). It should not be overlooked, therefore, that as introduced larvae mature they may contribute substantially to limiting further aphid increase. However, we have concluded that, for commercial needs, coccinellids would normally be released as larvae so the chosen species must be one which can be produced cheaply in large numbers. In this context, adult fecundity under artificial conditions is the most important thing to be considered. Fortunately, *C. sanguinea*, which appeared to be the most useful species in terms of biological efficiency, also produced the greatest number of eggs when fed on *M. persicae* or *A. gossypii* (Table 7). There is little confirmatory published work, but Szumkowski (1955) found that *C. maculata* adults produced

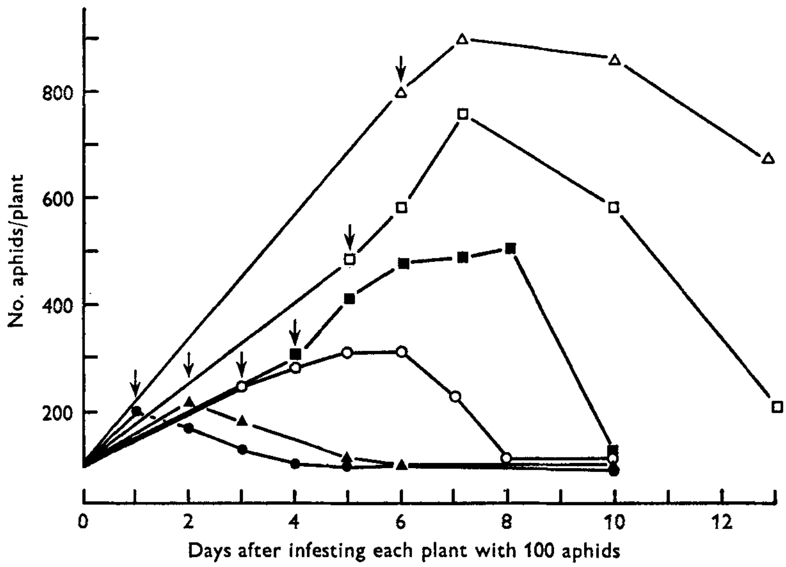

Fig. 1. Pattern of control achievement by ten coccinellid larvae introduced on to young cucumber plants infested by different numbers of aphids. (The symbols distinguish between plants carrying different aphid populations at the time of predator introduction ↓).

Table 6. *Control of* Myzus persicae *on chrysanthemums by* Adalia bipunctata *adults*

	Number of aphids	
	At introduction of adults	After 14 days
Control	1880	19,949
15 adults	1760	5,382
30 adults	632	2,223

Table 7. *Mean daily fecundity of adult coccinellids fed on different aphids*

(Number of observations in parentheses.)

	Myzus persicae	*Aphis gossypii*	*Acyrthosiphon pisum*
Adalia bipunctata	9 (4)	5 (7)	—
Coleomegilla maculata	8 (7)	8 (4)	9 (4)
Cycloneda sanguinea	28 (4)	25 (7)	4 (9)

five eggs daily when feeding on *A. gossypii*, while Blackman (1967) obtained seven eggs daily from *A. bipunctata* and five from *C. septempunctata* when fed on *M. persicae*. Sundby (1966) provides data for *C. septempunctata* which suggests a higher figure of about twelve eggs daily, while El-Hariri (1966) obtained twenty eggs daily from *A. bipunctata* fed on *Acyrthosiphon pisum*. Although egg production of all our species was higher on *M. persicae* (Table 7), it is difficult to mass-rear this aphid. It does not produce dense colonies, so fewer can be reared per unit space compared with *A. gossypii* or *A. pisum*. Undoubtedly, the latter aphid would have been the ideal host because mass-rearing techniques have been developed elsewhere (Halfhill, 1967). However, if *C. sanguinea* adults are fed continuously on *A. pisum*, egg production ceases after about 3 weeks despite the fact that the adults can survive on this aphid for several months. A rearing technique, based on that of Shands, Shands & Simpson (1966) for *C. septempunctata*, has therefore been developed using a mixed diet of *A. gossypii* and *M. persicae*, on which each adult produces an average of about twenty eggs daily (seventy-seven observations).

As, for commercial production, the highest possible oviposition rate is required, attention has been concentrated on natural rather than artificial diets. The current emphasis on the development of chemical diets in the U.S.A. may necessitate a re-assessment of our conclusions, as any artificial medium capable of sustaining reproduction would obviously be more suitable for factory production.

Another aspect of mass-production is the maintenance of healthy non-breeding stock of adults on a non-aphid diet. A number of diets were tested including water, brewers' yeast (both dry and with water), honey with water, honey with yeast and water, sugar and water, liver broth alone and with the addition of yeast and water. All the adults tested survived on sugar and water for a month, but some deaths occurred on other diets and difficulties were often experienced with fungal and bacterial contamination. Adults maintained on the sugar/water diet resumed oviposition 6–9 days after feeding on aphids.

CONCLUSIONS

This study was made to choose a coccinellid species for potential use in protected cropping. Of the four species originally tested, three proved unsatisfactory either because they could not effectively search the host plant or because they failed to produce eggs freely under artificial conditions.

However, the differences between them did not justify further screening while the rearing technique is based on an aphid diet. Should it prove possible to use other insect eggs, or purely chemical diets, as a food source it may be profitable to extend the screening if an efficient species is to be mass-reared with the greatest economy.

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