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PRELIMINARY EXPERIMENTS ON THE POTENTIAL OF HOVERFLIES [*DIPT. : SYRPHIDAE*] FOR THE CONTROL OF APHIDS UNDER GLASS

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Control of *Aphis gossypii* Glover populations on isolated cucumber plants grown at 21°C was achieved on days 2, 3, or 4 by larvae of *Metasyrphus corollae* (F.) hatched from eggs laid on the plants on day 0. With 45 % of hoverfly eggs viable, greater than 9 aphids per egg at the end of oviposition resulted in a failure of control. Larvae 1, 2, or 3 days old prevented aphid increase unless there were more than 15, 26 or 41 aphids per larva respectively. Continuous control on single caged cucumber plants was possible providing that the presence of 1 gravid hoverfly was maintained in the cage, but elimination of the aphid population was observed in only 1 instance. A possible role for hoverflies in crop protection under glass is discussed.

KEY-WORDS : *Metasyrphus corollae, Syrphidae, Aphis gossypii,* cucumber, chrysanthemum, biological control, aphid populations, predator-prey ratio.

Aphids became a problem on chrysanthemums in the UK mainly due to the appearance of clones of *Myzus persicae* (Sulzer) and *Aphis gossypii* Glover resistant to systemic carbamate and organophosphate insecticides (**Cross** *et al.*, 1983). This resistance led to the development of the fungal pathogen *Verticillium lecanii* (Zimm) Viégas (**Hall & Burges,** 1979). *V. lecanii* has given good control in many cases, but is not always effective because of the difficulty of maintaining the night-time humidity essential for germination and sporulation. Nor is it as effective against *A. gossypii* as against *M. persicae* since the former is a less active aphid and the disease is not so readily transmitted. *Macrosiphoniella sanborni* (Gillette) is rarely controlled by *V. lecanii* at all due to the low humidity on the chrysanthemum stems where it feeds (**Wardlow,** 1985). In addition, *A. gossypii* can cause occasional problems on cucumbers where an integrated programme of pest control is in use, but can be controlled by pirimicarb, a relatively selective insecticide, as at present only the chrysanthemum biotype of this species is resistant. There is therefore a need to develop additional biological control methods to supplement the existing programme and help forestall the arrival of further pesticide resistance.

The recent finding that the larvae of syrphid flies (mainly *Metasyrphus corollae* (F.) and *Episyrphus balteatus* DeGeer) could halt cereal aphid increase at low population densities in winter wheat (**Chambers** *et al.*, 1985), together with the discovery of naturally-occurring syrphid predation on chrysanthemums at a commercial nursery in West Sussex, suggested that these predators could be exploited for glasshouse aphid control. In view of the high fecundity of females and the substantial voracity of the larvae, both of which exceed those of the predatory midge, *Aphidoletes aphidimyza* (Rondani) (**Bondarenko & Asyakin,** 1981), syrphids offer the possibility of rapid control of those aphid populations with a high potential for increase.

This paper describes preliminary experiments using aphids and syrphids on single cucumber plants to establish whether *M. corollae* has the capacity to control *A. gossypii*. This aphid species was chosen because it has the highest intrinsic rate of increase of 4 species commonly colonising cucumber and chrysanthemum crops (**Wyatt & Brown,** 1977). It is therefore the most severe test of the predator's control potential, especially at the higher temperatures at which cucumbers are grown. The experiments were designed to find firstly, whether *M. corollae* could stop population increase of *A. gossypii* and initiate a decline in aphid numbers ; secondly, the ratio of predators to prey that would be effective ; and thirdly, for how long such control would last.

MATERIALS AND METHODS

Cucumber plants (cv. Bedfordshire) were grown in 13 cm diameter plastic pots and were infested at the 3-leaf stage with 20 to 800 *Aphis gossypii* of mixed instars. The aphids were left 1 to 2 days to settle. Each plant was placed into a culture of *Metasyrphus corollae* for up to 24 h for predator eggs to be laid beside the aphid colonies. A range of initial aphid:egg ratios was obtained by varying both the initial level of aphid infestation and the length of time the plant was left in the predator culture. A range of 11 to 403 eggs was laid per plant. Plants were removed from the predator culture, placed individually in perspex cages, (48 cm × 80 cm × 54 cm height) and the numbers of eggs and aphids counted immediately. Syrphid larvae and aphids were counted daily thereafter until aphid numbers were either extremely high or very low or until very few or no larvae remained on the plant. Eleven populations were established in this manner.

On a further 5 plants, between 20 and 120 aphids were introduced and after settling, the presence of 1 gravid female syrphid was maintained in each perspex cage, replacing from stock if necessary. Aphids, unhatched eggs, and larvae were counted daily.

Experiments and cultures were maintained at a constant temperature of 21 ± 2°C, in a long photoperiod (16 h light ; 8 h dark).

RESULTS

On the first 11 plants, the majority of syrphid eggs hatched on day 2 and the remainder on day 3, the initial aphid and egg count having been taken on day 0. When the initial egg and larval numbers were low in relation to aphids, the *Aphis gossypii* population grew rapidly, increasing 7.2 fold over 7 days (fig. 1a). On all other plants but 1, the aphid population was controlled, with decrease commencing on day 2, 3 or 4 due to predation by 1, 2 or 3 day-old larvae (examples, figs 1b, 1c and 1d respectively). The plant in fig. 1d collapsed on day 8 after wilting on days 6 and 7 due to the high aphid density, even though the aphid population was limited by predation.

The initial ratios of prey to predator ranged from 0.8 to 11.3 aphids per egg (the latter illustrated in fig. 1a), with control of the population resulting at all ratios up to and including 8.37 (fig. 1d). Since hatching was completed by day 3, peak larval numbers can be used as an approximate measure of the number of eggs hatched successfully. From this, the percentage hatch was a mean of 45.1 % (n = 10), ranging from 35.2 % to 52.6 %. One exception occurred where the *A. gossypii* population continued increasing even though the initial aphid:egg ratio was 5.8. However, in this case only 27.3 % of the eggs hatched. If the larvae on this plant had hatched from eggs that were as viable as on the other 10 plants, the initial aphid:egg ratio would have been 9.1. Thus at 45 % successful hatch, more than about 9 aphids per egg at the end of oviposition would result in a failure of control. The low viability of eggs was mainly due to sterility, possibly as a result of insufficient matings in the culture.

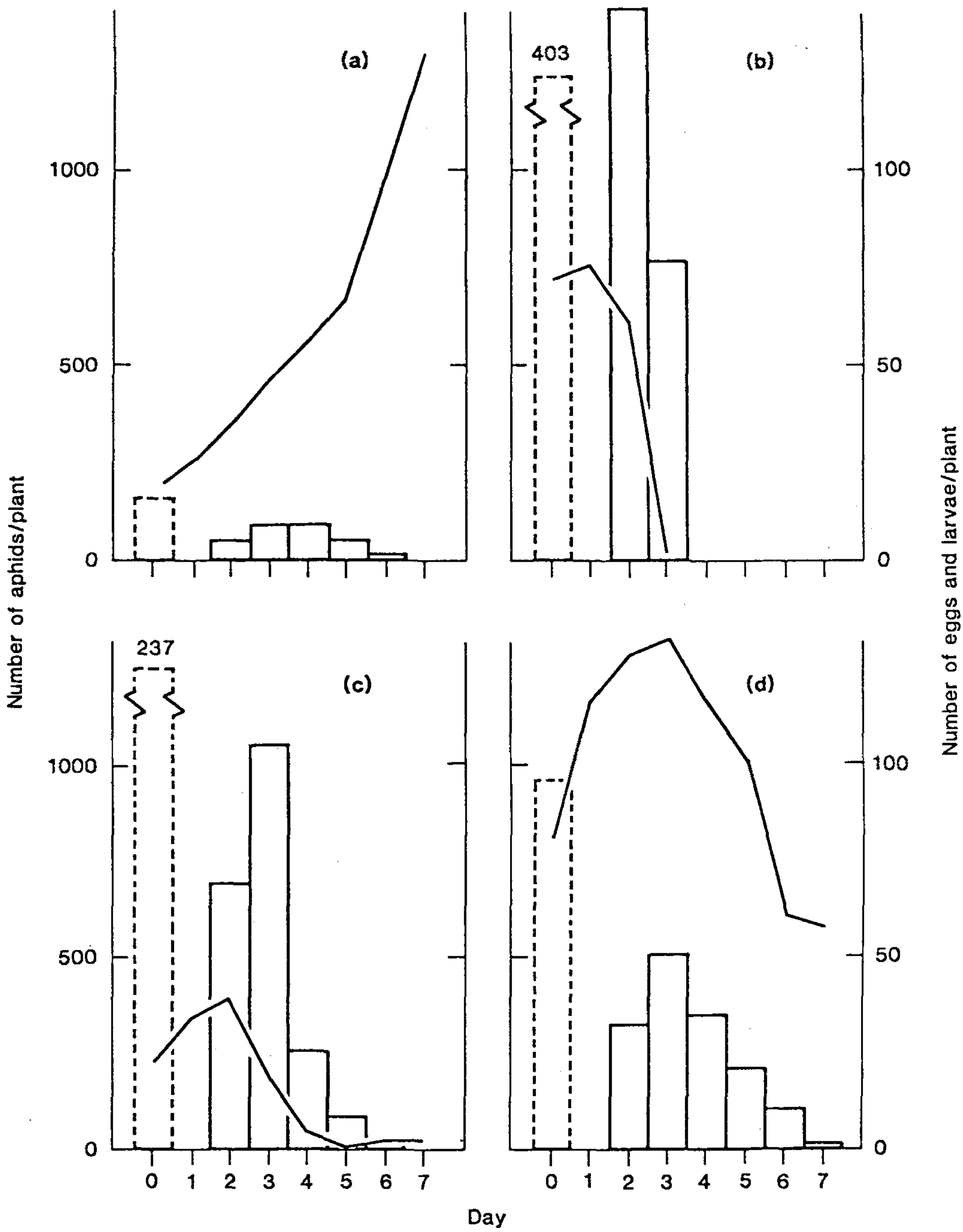

Fig. 1 (a-d). Number of aphids (———), eggs (dashed histograms), and larvae (solid histograms) on days 0 to 7 in 4 cases with different initial ratios of aphids to eggs.

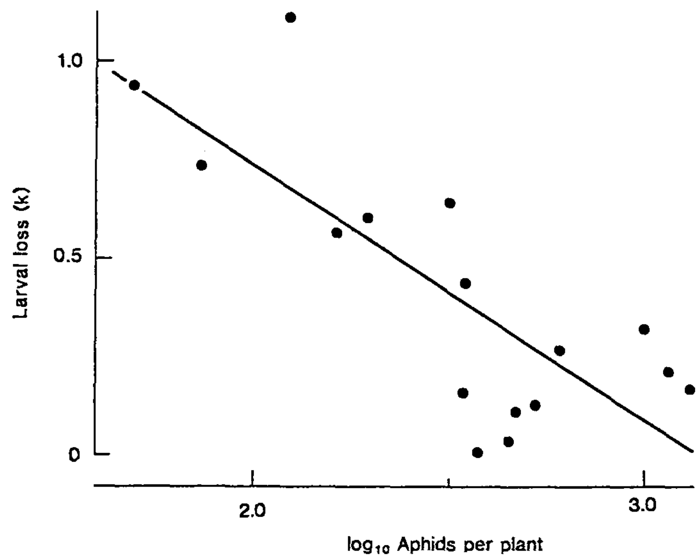

Fig. 2. Larval loss ($k = \log_{10}$ (number per plant on day d/number on day d + 1)) in relation to aphid density ($\log_{10}$ number per plant on day d). $k = 1.994 - 0.632x$, $r = 0.771$, $P < 0.001$. Data from all plants on each day from larval population peak.

The desiccation and cannibalism of fertile eggs appeared to be less important, although no estimate of the loss due to these factors was made.

Numbers of larvae on the plants decreased after day 2 or 3, and by day 7 there were not more than 3 larvae remaining on any plant. This loss was due to searching during which some larvae moved down the cucumber stem and onto the soil surface and pot rim. Larval loss was significantly and inversely related to aphid density (fig. 2) ; at higher aphid densities fewer larvae left the plant in search of prey. Thus as control was achieved and aphid numbers fell, larvae searched more widely for prey and the number of larvae declined. Larval loss was noticably less rapid where aphid numbers were higher (c.f. figs 1c and 1d).

On day 2, the 1st day of larval life, the ratio of aphids to larvae ranged from 3.3 to 131.0. On plants where the ratio was in excess of 15, the aphid population continued increasing over the next 24 hours. Similarly, the aphid population decreased over the following 24 h period only if there were fewer than 26 aphids per 2-day-old larva, and the threshold for 3-day-old larvae was 41 aphids per larva (fig. 3). After 3 days, the ratios are unreliable as fewer larvae remained on the plants or aphids had declined to a lower level.

On the 5 extra plants, the continuous presence of 1 gravid female resulted in the aphid population remaining at a low level for up to 28 days, after which the experiment was discontinued (example, fig. 4). Between day 12 and day 17, difficulty was experienced in finding fully gravid females in the stock culture and very few eggs were laid on the plant illustrated. As a result, the aphid population increased but was controlled after day 22 as more eggs were laid. On 2 of the remaining 4 plants, aphids increased out of control because few gravid females were available in the stock culture. On 1 cucumber the aphid population was controlled continuously for 24 days before the experiment was terminated due to the size of the plant in the cage. On the remaining cucumber the aphid population was eliminated by the predators on day 8.

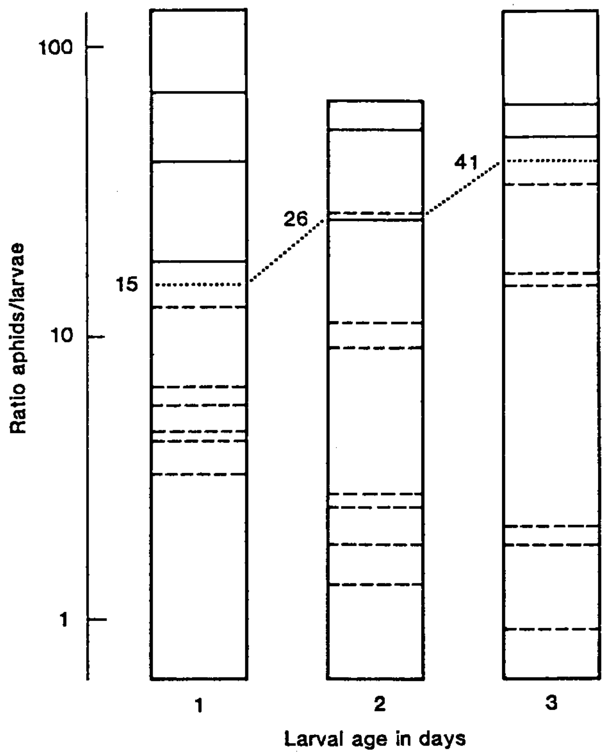

Fig. 3. Values for the ratios of aphids:larvae which resulted in aphid increase (———) or decrease (--------) over the following 24-h period for 1, 2, and 3 day-old larvae, with inferred threshold ratios for control (··········).

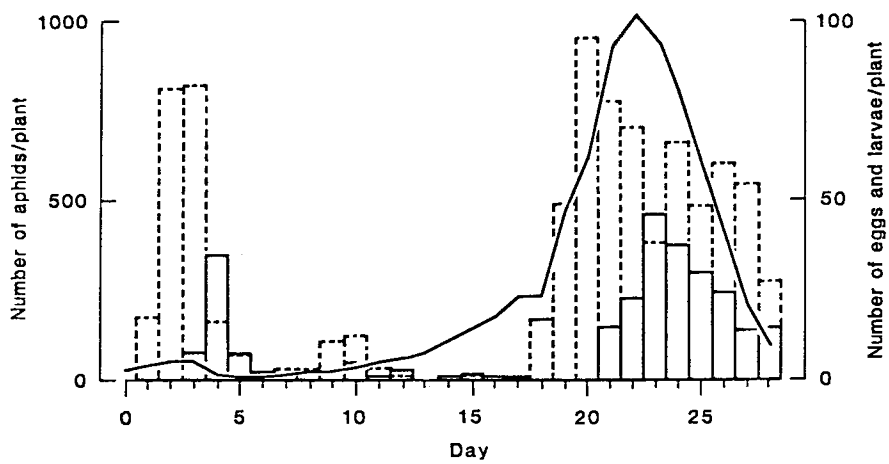

Fig. 4. Number of aphids (———), eggs (dashed histograms), and larvae (solid histograms) on a plant kept with 1 gravid female *M. corollae*.

DISCUSSION

The feasibility of using predatory insects for the biological control of aphids in protected crops was investigated by **Scopes** (1969) using *Chrysopa carnea* L. and by **Gurney & Hussey** (1970) for 4 coccinellid species. Because of the cost of rearing and the problems of establishing an even distribution of predators throughout the crop, chrysopids and coccinellids were unsuited for biological control in a commercial glasshouse. In contrast, the predatory midge, *Aphidoletes aphidimyza*, offers considerable potential for aphid control and has been mass-reared and sold for use on commercial crops in Finland (**Markkula & Tiitanen,** 1985). While mass production is easy, the low fecundity of the females is a major disadvantage (**Harris,** 1982).

In the present study, control of *Aphis gossypii* by *Metasyrphus corollae* was achieved rapidly, but predation pressure was sustained for only a few days. Both the duration of incubation of the eggs and the rate of development of larvae in *M. corollae* are comparable with those of *A. aphidimyza* and are more rapid than in other predators considered for control of aphids under glass. The eggs of *M. corollae* hatch after 45 day-degrees C above 4°C (unpublished data), which is approximately 2.7 days at 21°C, and the larvae complete development in 7.5 days at the same temperature (**Adams,** 1984). Eggs of *A. aphidimyza* hatch in about 2 days and larval development is completed in 5.5 days at 23°C (**Bouchard** *et al.*, 1981). A short incubation and speedy larval development are advantageous in a predator considered for biological control of a rapidly increasing pest, especially *A. gossypii.*

In the laboratory, continuous control proved possible on single plants with total elimination of the aphids occurring in 1 case. However, *A. gossypii* soon began to increase following temporary cessation or slowing of hoverfly oviposition. This release from control was probably accentuated by the density-related movement of larvae away from the leaves. **Bondarenko & Asyakin** (1981) observed the same dispersal tendency at low aphid densities in experiments using hoverfly larvae on single leaves of cucumber. Predatory control would be more stable in a plant stand where larvae can redistribute between plants and thus help compensate for any short-term absence of ovipositing females. More stable control would arise with the slower increase rates of *Myzus persicae* and *Macrosiphoniella sanborni* especially at the lower temperatures used for growing chrysanthemums.

Larvae of *Metasyrphus corollae* were apparently not unduly deterred or hindered by the presence of hairs on the cucumber leaf surface. The hairs offered some impediment to movement of larvae a few days old, although very small larvae were able to move between hairs. In contrast, leaf hairs were a major obstacle to larvae of the coccinellid *Coleomegilla maculata* De Geer (**Gurney & Hussey,** 1970) which were disturbed and dropped from the plant.

After infestation, aphids colonised mainly the lower leaf surfaces, and most eggs were laid beside or among them. It was observed that predation frequently disturbed *A. gossypii* causing them to move to upper surfaces of the leaves, usually on day 2 or 3, after which they were quickly followed by the larvae. Such movements signify that predation is taking effect, but in a commercial crop, aphid redistribution could give a misleading impression of the effectiveness of control if both upper and lower leaf surfaces were not inspected.

M. corollae is probably less suitable than *A. aphidimyza* for innoculative releases intended to establish a predator population which maintains itself over several generations. A source of pollen, necessary for gametogenesis, would have to be provided if this was not available from the chrysanthemum or cucumber crop itself. In addition, pre-reproductive females are inclined to disperse and in sunny weather would leave the glasshouse through the vents, unless these were netted. Field-collected flies behave similarly (**Bondarenko & Asyakin,** 1981).

The advantages of a higher female fecundity and larval voracity than in *A. aphidimyza* suggest that *M. corollae* would be better suited for regular low-density inundative releases to combat sporadic outbreaks of *A. gossypii* or *M. sanborni*. Rather than attempt to obtain continuous aphid control in chrysanthemums, *M. corollae* could be used to supplement control by *Verticillium lecanii*, or to suppress *A. gossypii* in cucumbers where peat-bag culture and the application of polybutenes and deltamethrin ("Thripstick") to capture thrips (**Pickford,** 1984) precludes *A. aphidimyza* control due to absence of soil pupation sites. Inundative release of eggs or larvae would be too time-consuming for the grower, but several releases of gravid females would be a quick and simple task. Gravid females hover among foliage and search over leaf surfaces, depositing eggs beside or within aphid colonies, and are less likely to disperse away from the crop than newly-emerged flies.

Further work is now needed to assess the effectiveness of adult hoverflies and their larvae in searching for small colonies of aphids in both chrysanthemums and cucumbers, to test the stability of control in a stand of plants, to find the numbers of flies needed for protection of a given acreage of crop, and to improve the efficiency and cost of hoverfly rearing methods.

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RÉSUMÉ

Etudes préliminaires sur les possibilités des Diptères Syrphidae
pour le "control" des populations d'Aphides en serre

On parvenait à réduire des populations d'*Aphis gossypii* Glover fixés sur plants isolés de concombres, croissant à 21°C, au moyen de larves de *Metasyrphus corollae* (F.) écloses d'œufs pondus sur les plantes au tout début de l'expérience (jour 0) en 2, 3 ou 4 jours. Avec 45 % d'œufs viables de Syrphes, une proportion supérieure à 9 pucerons/œuf en fin de ponte, entraîne l'échec du "control". Les larves âgées de 1, 2 ou 3 jours empêchaient l'accroissement des populations à moins qu'il y eut plus de 15, 26 ou 41 Aphides/larve respectivement. Le "control" continu sous cage sur de simples plants de concombres était possible pourvu que la présence d'une seule ♀ gravide de Syrphe soit maintenue en cage, mais l'élimination de la population de pucerons n'était observée que dans 1 seul cas. Le rôle possible des Syrphes dans la protection des cultures protégées est discutée.

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