REARING NATURAL ENEMIES OF APHIDS FOR ECOLOGICAL STUDIES[1]

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Introduction

Recent books on parasites of aphids (Starý, 1970) and on coccinellids (Hodek, 1973) include rearing methods but in passing only, when discussing the biology of the species concerned. A text on biological control (De Bach *et al.*, 1964) deals with rearing but like Smith (1966) it emphasizes economy in mass rearing and the use of artificial diets. We needed a system of rearing which was simple and efficient yet easily adapted to the different needs of Coccinellids, Chrysopids, Aphidiids and hyperparasites. We were not interested in long term or mass rearing but in rearing small numbers of different species just long enough to measure some biological attribute needed for our studies on the impact of natural enemies on the population dynamics of the prey. Because of the number of species to be reared, our philosophy is based on the view that the insects should do most of the work, which obviously saves labour and also seems to result in more vigorous insects. This paper reports our general methods and the modifications that have allowed us to maintain stocks of 3 parasites and 3 hyperparasites of aphids; 2 chrysophids and 7 coccinellids.

Methods and Discussion

The basic rearing system requires continuity in production of plants and aphids and a controlled, uniform environment. Stable conditions reduce the amount of attention needed by the colonies, permit accurate scheduling of the work and give predictable results.

Plant and Aphid culture. We plant 10 broad bean seeds (*Vicia faba* L., cv. Exhibition Long Pod) per pot in UC mix C, Fertilizer I (Matkin and Chandler, 1957) in 15 cm round, plastic pots. This is done four times per week. When the plants are newly sprouted they are heavily infested with pea aphids, *Acyrthosiphon pisum* (Harris), and the pots are placed in a room maintained at 20 ± 2°, 60 ± 10% RH and provided with 1000 ± 100 lux of light, 16 hr per day (± indicates the normal ranges). The plants and aphids are ready for use in 7-8 days, when the plants are 20-40 cm high but are still actively growing. The pots of infested plants are then either moved into rearing cages or the aphids from the plants are harvested. It is advantageous to hold the aphid stock colonies in another room, distant from the parasite rearing area, otherwise the aphids must be caged.

We use UC mix because of its homogeneity and constant composition over time; but more importantly, one pot can retain about 500 cc of water and absorb this amount in 5-10 sec. This reduces watering to 2 times per week and minimizes the risk of accidental drought. The environmental conditions are ideal for the rapid production of high numbers of large pea aphids. The stock of aphids we use is an 'ecotype' selected over 15 years and is ideally suited to these conditions, In fact, it does poorly at 5° warmer or in cooler or dryer conditions.

Rearing cages. We use cages of varying sizes and construction. We have not found dimensions or shape to be important except for syrphids (Frazer, 1972), provided that the

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cages have transparent roofs and forced air supply. Air movement is essential in maintaining constant favourable conditions inside the cages. A squirrel cage fan (1/6 hp) assembly fitted with a rheostat to control the flow, supplies air to the cages through cardboard or wooden ducts. The supply is minimal, only enough to prevent condensation and heat build up, yet insufficient to cause excessive evapotranspiration from the plants. A large number of cages can be supplied by one fan, provided that each cage is connected in parallel to a larger duct to give an equal air flow to the cages. We have one unit with 6 cages on both sides of a built-in air duct, from which another worker supplies air to 60 single pot cages, using the same small fan assembly. In fact, a plant in a plastic bag supplied with forced air makes a suitable temporary cage.

Rearing coccinellids. Field collected adults are placed in a cage with as many pots of aphid infested broad bean plants as the cage will hold. The object here is to adjust the ratio of adult coccinellids to the number of aphids on the actively growing plants so that the coccinellids neither eat all the aphids in a few days nor allow the aphids to increase greatly, thereby killing the plants. The starting ratio is not critical but a good ratio prevents unscheduled maintenance. A suitable ratio is 200 adults with 4 pots of 10 plants each.

The coccinellids will oviposit on the plants but handling eggs on plants involves considerable time and disturbance to the aphids. We found that coccinelids prefer to oviposit in crevices in the cages, in folded leaves and under the rims of pots. If single faced, corrugated, cardboard strips are placed in the cage with the corrugations running across the width, almost all egg laying will occur under and in the corrugations. Eggs deposited on exposed areas are soon eaten by the adults. Egg cannibalism is minimal with corrugated cardboard, unless the strips are left in the cage for days. If the strips are removed and replaced daily, vast numbers of eggs can be produced. However, we use the strips only to start another generation, which happens every other month.

The cardboard strips for oviposition have other advantages: large numbers of eggs are deposited in a short period thus allowing synchronization of hatching; and the cardboard has a large surface area to volume ratio. The last two factors greatly reduce the mortality caused by young larvae eating unhatched eggs of neighboring batches and by older larvae eating younger ones.

We put about 10 feet of the strips bearing eggs in a 1/2 gal ice cream carton and when the eggs are ready to hatch, after about five days, we add a surplus of aphids. When the larvae have moulted once, they and the cardboard strips are placed in a large cage and maintained like the adults. When the larvae reach the fourth instar, pots of aphid-infested plants must be added every 2-3 days to prevent cannibalism. Again the cardboard reduces mortality, because the larvae seek out secluded areas before moulting or pupating. Pupation, however, also occurs in other areas.

We have reared the following species using these methods: *Adalia bipunctata* L., *Coccinella californica* Mannerheim, *C. undecimpunctata* L., *C. trifasciata perplexa* Mulsant, *C. johnsoni* Casey, *Cycloneda munda* Say and a *Mulsantina* species.

Rearing chrysopids. We reared two *Chrysopa* species using essentially the same methods as for coccinellids. Corrugated cardboard is useful for chrysopids for the same reasons as for coccinellids, except that adults do

not oviposit on it preferentially. We simply ensure that cages of larvae are well supplied with the cardboard strips for moulting and pupating. The most important requirement is to use newly sprouted bean plants. This promotes synchronous rearing of the aphids with the chrysopid larvae.

Rearing parasites. We have reared *Aphidus ervi* Haliday, *A. smithi* Sharma and Subba Rao and *Praon pequedorum* Viereck.

Cannibalism does not occur with the parasites, which greatly simplifies rearing. Newly sprouted plants are used, 5-10 cm high, so that the aphids are reared in the cage with adult parasites. If more than 20 ♀ parasites are introduced into a new cage, they 'oversting' and eliminate the aphids; if fewer than 20 ♀ are used, aphid reproduction appears to keep up with oviposition pressure and thus ensuring a large number of parasites in the next generation. If too few parasites are used, the aphids increase rapidly and kill the plants before the parasites have time enough to pupate. If parasites of uniform age are needed, larger plants with more aphids are used. But here a large number of ♀ parasites are put in the cage and removed 24 hr later. Such synchronous colonies are essential for rearing hyperparasites.

The two *Aphidius* species present no problems, but *P. pequodorum* does well only when we shut off the air flow , place a dish of water in the cage and let honeydew accumulate. We add a previously heavily infested pot of plants to provide honeydew. Our experience is that messy cages promote good production of this sp. We supply honey as droplets on pieces of wax paper taped to the side of the cages for all parasite species.

Rearing hyperparasites. We have successfully reared *Asaphes vulgaris* Walker, *A. californicus* Girault and a *Dendrocerus sp.* on *Aphidus ervi* in pea aphids. The only problems are to synchronize the plant, aphid and primary parasite production; and to ensure the proper ratio of aphids to primary parasites. We use synchronous parasite rearing for this purpose. When the primary parasites are removed after 2-3 days association with the aphids, a maximum of 20 ♀ hyperparasites are added. The hyperparasites then oviposit in the previously parasitized aphids in the preferred stage of development. The cage conditions for *P. pequodorum* also suit the hyperparasites but honey is not essential.

Mass rearing conditions. The basic rearing systems described are easily upgraded to produce very large numbers of coccinellid eggs and parasite adults. From a young stock of 100 ♂ and 100 ♀ coccinellids, 500 eggs per day may be produced for up to four months. The maintenance involves at most 1 hr per week, much of which is spent in cutting cardboard. The eggs may be safely stored at 10°C for 10 days, but such treatment greatly increases the hatching time when they are returned to warmer conditions. The most critical aspect of the system is to have plants and aphids in excess, particulaly when coccinellid larvae are in their 3rd and 4th instars.

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