Project title:	Artificial refuges for enhancing populations of predators of natural enemies of pests in apple and pear orchards
Project number:	TF 93 [Previously APRC SP 93]
Report:	Final report 1996
Project leader:	Dr M Solomon, HRI East Malling
Key words:	apple, pear, refuges

This project report was originally issued by the Apple & Pear Research Council, under project number SP 93.

Final Report to APRC on Project SP 93

Artificial Refuges for Enhancing Populations of Natural Enemies of Pests in Apple and Pear Orchards

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Summary

Three types of artificial refuge were placed in apple and pear orchards. During the summer months large numbers of the common earwig, *Forficula auricularia*, were found in bottle refuges containing rolls of corrugated cardboard hanging from branches and attached to tree trunks. Cage refuges containing chopped straw also attracted earwigs. Very few other arthropods were found in refuges during the summer. During the winter months, spiders were the most common arthropods found in both bottle and cage refuges; some predatory mites, *Typhlodromus pyri*, were also extracted from straw in the cage refuges. Large numbers of *T. pyri*, were found in cloth bands attached to tree trunks and branches throughout the winter months.

Introduction

Many different species of predator and parasite attack pests of apple and pear. These natural enemies can act as a regulating factor for pests, and they offer potential for use as a powerful non-pesticidal control technique. As a result of a largely MAFF-funded programme of strategic research, involving field sampling and laboratory feeding studies, we are familiar with the range of predatory species that attack orchard pests; much less is known about the parasites of the pests. Many of these natural enemy species are affected adversely by pesticides. The need to minimise damage to some of these beneficial species is one of the major factors governing the development of Integrated Pest Management (IPM) techniques. The only natural enemies currently exploited on a wide scale in orchards are organophosphorus (OP) -resistant *Typhlodromus pyri* (Typhs), against spider mite and rust mite on apple, and anthocorids, mainly *Anthocoris nemoralis*, against pear sucker (Solomon, 1989; Solomon *et al.*, 1989; Solomon *et al.*, 1993). The move towards reduced pesticide use, and the availability of more-selective pesticides, allows greater survival of natural enemies in orchards.

Many species of insects and mites on fruit trees seek refuges, or hiding places, as

a daily sheltering place or as an overwintering site. The sites they seek are often cracks and crevices in the bark, but modern small fruit trees offer far fewer sites of this kind than large old trees. This deficiency could to some extent be counteracted by the provision of various kinds of artificial refuge.

Materials & Methods

Types of Refuge

Three types of artificial refuge were constructed for this study.

1. Bottle refuges. These were made from 1 litre plastic drinks bottles. The bottom of each bottle was removed, a strip of corrugated cardboard, 15 cm wide x 115 cm long, was rolled to form a cylinder and inserted, and a short wire pulled through the plastic near the base to secure the cardboard in position. These bottles were either suspended by wire from branches, or attached tightly to trunks, branches or tree stakes with wire.

   Some insects are known to be attracted to particular colours, e.g. aphids to yellow traps (Taylor & Palmer, 1972) carrot root fly to green-yellow traps (Collier & Finch, 1990). In order to test the possibility that some flying insects might be attracted to particular colours, some bottles were painted black, green, or yellow (twelve of each colour), so that numbers of arthropods found in them could be compared to those in clear bottles.

2. Cage refuges. These were made from galvanised wire mesh (1.5 cm square mesh) rolled and secured into a tube 18 cm long of diameter 7 cm. One open end was closed by threading two pieces of wire through the tube. The tube was then filled loosely with chopped straw. A plant pot saucer, 13.5 cm diameter, was secured to the other end of the tube, to provide protection from rain, and the completed refuge was then suspended with wire from a branch.

3. Cloth bands. These consisted of strips of hessian, or of velour (a fine pile material), of various lengths and widths. The material was wrapped around branches or trunks of trees and secured with an adhesive tape band.

Extraction of arthropods from refuges

1. Bottle refuges. The bottles were returned to the laboratory separately in polythene bags, and the cardboard removed on a refrigerated table with a surface temperature of approximately 0°C; this slowed down any emerging arthropods, so they could be collected more easily. The cardboard was torn apart, to remove any arthropods sheltering within the ridges of the card. Arthropods from each bottle were kept separately for identification.

2. Cage refuges. The cages were returned to the laboratory separately in polythene bags. To collect any sheltering arthropods, the straw was removed from the cages and

placed in Tullgren funnels; these consist of funnels above which are suspended low wattage electric bulbs. Arthropods moving away from the light and heat generated by the bulb are collected in a tube containing alcohol, attached beneath each funnel.

3. Cloth bands. These were returned separately to the laboratory in polythene bags. Large arthropods were removed on the cold table. Small arthropods were removed from the pile of the fabric by placing the bands in Tullgren funnels.

Experimental sites

Experiments were done in orchards at HRI East Malling. Bottle and cage refuges were put out in apple and pear orchards and in some surrounding alder and hawthorn windbreaks. Cloth refuges were put out in apple orchards as overwintering shelters. Experiments were done during summer (1994 & 1996), to investigate short-term use and during winter (1994/5 and 1995/6), to examine overwintering use of refuges by arthropods. During the summer months the refuges were emptied at approximately two week intervals. Refuges that were to be left out over winter were positioned in the orchard by the end of August. They were emptied at intervals throughout the winter.

Results

The arthropod species caught in greatest numbers during the summer in bottle refuges attached to trunks and tree stakes in apple and pear orchards, and alder and hawthorn windbreaks, was the common earwig, *Forficula auricularia* (Tables 1, 2 , 3, 4 & 5). Other arthropods were caught at all sites but numbers were very low; most were spiders, but a few *Anthocoris nemoralis* and coccinellids were found in refuges in the pear orchard. The arthropod found in the greatest numbers in hanging bottle refuges was also the common earwig; however, numbers were much lower than in trunk or stake refuges. In 36 samples (6 bottles and 6 sample dates) the total number of earwigs collected in 1994 from yellow, green, black and clear refuges was 97, 150, 182 and 243 in apple, and 8, 11, 12 and 5 in pear. There were no statistically significant differences between numbers of earwigs caught in traps of different colours on each sample date in either apple or pear. The total number of other arthropods found ranged from 1 - 9 in both apple and pear, and was too low for a valid statistical analysis of differences between colours. There was no difference in numbers of earwigs found in bottle refuges attached to tree stakes or trunks in a pear orchard (Table 6) indicating that earwigs are likely to move up into the tree canopy from the ground on a range of upright supports. More earwigs were caught in the apple orchards used for this trial than in the pear orchard (Tables 1, 2, 4 & 5). Earwigs were also caught in the cage refuges; the mean number caught per refuge was 7 during August and September.

Spiders were the most abundant arthropods found in both bottle and cage refuges during the winter months. During the 1994/95 winter the mean number per refuge was 10 in hanging refuges and 21 in trunk bottle refuges in a pear orchard; numbers were much lower in apple, with a mean number of 2 per refuge. The most commonly found spiders belonged to the families Theridiidae, Clubionidae and Thomisidae (Table 7).

During the 1994/95 winter means of 0.5 male and 1.6 female *Anthocoris nemorum* were found in refuges in an apple orchard. Numbers were lower in the 1995/96 winter, with means of 0.3 females and 0.3 males per refuge in apple. Low numbers of *A. nemorum* females were also found in refuges in a pear orchard in the 1995/96 winter; mean numbers were 0.3 per refuge; no males were found. In the winter of 1995/96 a mean number of
2 spiders per refuge was found in both apple and pear orchards. The most commonly found spiders were Thomisidae and Theridiidae (Table 8). Overwintering predatory phytoseiid mites, *Typhlodromus pyri*, were extracted from straw in the cage refuges.

Large numbers of *T. pyri* overwintered in the sacking and velour bands, with maximum numbers of more than 350 per band. Hessian bands yielded slightly more phytoseiids than velour bands. Oribatid and tyroglyphid mites were also found in large numbers.

Discussion

Earwigs overwinter in underground nests, which they excavate in late autumn. Eggs are laid in winter and early spring and normally hatch before full bloom in apple. Some females lay a second batch of eggs in May or June. Immature earwigs leave the nest after moulting from first to second instar; they feed at night and shelter during the day. Late instar earwigs tend to feed and shelter in the tree canopy.

In our trunk bottle refuges, numbers of immature earwigs declined during August. By early September all earwigs caught were adults. In general, more females than males were found in the refuges. Total numbers of earwigs declined during September, as adults left the tree to prepare overwintering nests. Since there was no difference in the numbers of earwigs collected from refuges on tree trunks or stakes, it should be possible in young orchards to provide refuges or traps for earwigs on stakes close to the trees.

Earwigs may consume other insects that are sheltering in the refuges. As earwigs were found in large numbers in some of the hanging refuges, it is evident that suspending bottles from a branch is not an effective means of excluding them from refuges. The design of refuges that excludes earwigs is being investigated in current MAFF-funded research.

All arthropods collected from refuges were removed from the orchard, so those collected on the next sampling occasion were ones that had remained on the tree, or had recolonised from the orchard floor. Thus it is evident that there are very large populations of earwigs in some orchards. The apple orchards used in our trials had larger populations of earwigs than were found in our pear orchards. This may reflect the greater variety of possible prey species found in apple compared to pear (Solomon, 1987).

Earwigs are not normally considered a pest; however they may cause secondary damage to fruit by enlarging holes caused by other factors, and the accumulation of their frass around the stalk end of multiple fruit clusters may downgrade fruit. Earwigs are voracious predators of the green apple aphid *(Aphis pomi,* (Phillips, 1981)), the fruit tree

red spider mite *(Panonychus ulmi,* (Phillips, 1981)), the woolly aphid *(Eriosoma lanigerum,* (Ravensberg 1981)) and pear psyllids *(Cacopsylla* spp. (Lenfant *et al.,* 1994)). The latter authors showed that a third instar earwig larva could consume up to 1000 eggs of *C. pyri* per day. Thus earwigs have the potential to control some pests in apple and pear orchards.

Very few flying arthropods were found in the hanging bottle refuges. The most common were species of coccinellid, which are mainly predators of aphids. There appeared to be no added benefit to colouring hanging bottles refuges; flying arthropods did not appear to be attracted more to either the yellow or green bottles, colours known to be attractive to certain species. Sengonca & Henze (1992) found that overwinter survival of the green lacewing, *Chrysoperla carnea*, was enhanced by providing refuges and McEwan (1995) demonstrated that lacewings are attracted to yellow traps. Maredia *et al.,* (1992) showed that some species of coccinellid were attracted to yellow, and that green lacewings were attracted to yellow, green and red. However, no lacewings were found in any of our bottle refuges and coccinellids did not seem to be attracted to the yellow traps.

The most important predator of pear psyllids in UK pear orchards is *Anthocoris nemoralis*. *A. nemoralis* is susceptible to broad spectrum insecticides, so the current management strategy for pear psyllids is to apply a pesticide early in the season if necessary, before anthocorid adults return from overwintering sites outside the orchard (Solomon *et al* 1989). The Pest-Man™ forecasting system enables any necessary pesticide applications to be timed precisely to reduce damage to anthocorid populations (Morgan & Solomon 1992). The possibility of protecting anthocorids from pesticide sprays by providing artificial refuges within and around the orchard was tested in this trial. Anthocorids did use the bottle refuges in the pear orchard, but in low numbers, suggesting that this techinque is not a viable proposition for managing numbers of predators. Anthocorids did not use any of the refuges, either within the pear orchard or in adjacent windbreaks, as overwintering sites in the 1994/95 winter. However low numbers of *Anthocoris nemorum* were found in refuges in an apple orchard during both winters and in the pear orchard in the 1995/96 winter; this species is more of a generalist predator than *A. nemoralis* which in pear preferentially preys on psyllids.

The cage refuges did not attract large numbers of arthropods in the summer months. However, they were used by predatory mites, and by spiders, especially in the pear orchard in the winter months. Spiders have been reported to reduce populations of an aphid, *Sitobion avenae*, by 37% in winter wheat (Sunderland *et al,* 1987). However, little is known of the effect of predation by spiders in apple and pear orchards. Sunderland (1988) states that 43 species of spider have been reported feeding on aphids in fruit trees, so they may have potential for pest control in orchards. Of the three most common families of spiders found in the current trial, Clubionidae and Thomisidae are active hunters, and Theridiidae produce sticky webs.

The predatory mite *Typhlodromus pyri* is an important predator of spider mite in apple. *T. pyri* overwinter as fertilised adult females, usually in cracks and crevices in the bark. Winter mortality can be very high. Chant (1959) calculated mortality in one orchard in SE England to be 97%. Modern apple trees tend to be small and smooth

barked; it is possible that a shortage of overwintering sites may be one factor limiting the number of *T. pyri* that can overwinter successfully. Large number of *T. pyri* were collected from the hessian and velour bands. Thus the provision of artificial refuges may increase overwinter survival of *T. pyri* in dessert orchards. Higher numbers of phytoseiids were collected from bands in dessert orchards at HRI East Malling than in cider orchards in the SW of England, where hessian bands were used to monitor overwintering populations of mites (Fitzgerald & Solomon, 1996). This may be because cider trees are larger than dessert trees and have more crevices in the bark to act as natural overwintering sites. The other species of mites found in the cloth bands, oribatids and tyroglyphids, are not predatory and are not known to cause damage to fruit trees; they generally feed on algae on bark.

Cloth bands have been used in orchards in Switzerland (Baillod and Guignard 1984) to collect large numbers of phytoseiids to introduce into orchards with no natural populations of the predator. The same procedure could be used in UK apple orchards to reintroduce *T. pyri* if populations are destroyed by inappropriate pesticide usage.

Conclusions

1. Bottle refuges, either hanging or attached to tree trunks, and cage refuges are unlikely to attract large numbers of flying arthropods in apple or pear orchards.

2. The provision of bottle or cage refuges may increase the number of spiders that successfully overwinter. Further work is needed to determine the importance of spiders as predators in orchards.

3. The provision of bottle or cage refuges in young trees may increase the number of earwigs remaining on the trees. This would increase predation on pests such as pear psyllids and aphids.

4. Bottle and cage refuges could be used to trap and to move earwigs from orchards. This may be particularly useful close to harvest in cultivars that may be prone to fruit damage by earwigs. However it is not likely that earwigs could be 'trapped out' totally unless trees are sticky-banded around the trunk to prevent recolonisation of trees.

5. Cloth bands may increase overwinter survivial of predatory phytoseiid mites in apple orchards. Mites could be distributed to orchards that do not have large populations of predators by transferring bands from one orchard to another.

Acknowledgements

We acknowledge the assistance of Andrew Tullett, Naomi Turley and Rebecca Jolly with the practical work.

Table 1. **Mean numbers of arthropods found in clear bottle refuges attached to trunks in an apple orchard during 1994**

Date collected	No. of refuges	Earwigs						Other arthropods	
		male		female		immature			
		mean	SE	mean	SE	mean	SE	mean	SE
30 August	12	32.3	8.0	29.0	5.4	9.0	3.3	0.4	0.1
7 September	20	18.4	1.9	37.9	3.2	1.5	0.3	0.5	0.1
14 September	19	11.7	1.8	15.9	1.7	0.3	0.2	0.9	0.3
22 September	15	10.3	1.1	16.7	1.4	0.1	0.1	0.1	0.1
29 September	16	13.2	1.6	17.8	2.2	0.1	0.1	0.3	0.2
10 October	16	2.7	0.6	4.8	1.2	0.1	0.1	0.5	0.2

Table 2. **Mean numbers of arthropods found in clear bottle refuges attached to support stakes or trunks in a pear orchard during 1994**

Date collected	No. of refuges	Earwigs						Other arthropods	
		male		female		immature			
		mean	SE	mean	SE	mean	SE	mean	SE
17 August	12	6.2	1.0	8.0	1.2	1.1	0.4	0.5	0.2
2 September	12	4.8	1.1	10.1	1.2	0		1.1	0.3
9 September	20	7.0	1.5	8.7	1.3	0		0.5	0.3
19 September	20	4.8	1.2	7.5	1.5	0		0.7	0.2
26 September	16	0.9	0.3	1.8	0.6	0		0.4	0.2
7 October	16	1.1	0.4	1.2	0.4	0		0.4	0.1

Table 3. **Mean numbers of arthropods found in bottle refuges hanging in windbreaks during 1994**

Date collected	No. of refuges	Alder								Hawthorn							
		Earwigs						Other arthropods		Earwigs						Other arthropods	
		male		female		immature				male		female		immature			
		mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE
13 July	4	0.8	0.5	121	38.6	0		0		0.5	0.3	27.0	15.8	0		0	
12 August	4	92.3	8.4	154.5	23.8	96.5	19.7	0		12.3	2.3	23.0	4.6	11.5	2.1	0	
16 August	3	--	--	--	--	--		--		1.7	0.3	6.7	1.2	4.3	1.2	0	--
7 September	4	1.5	1.2	1.0	0.4	0		0		--	--	--	--	--		--	
14 September	4	3	1.5	4.5	1.9	0		0		--	--	--	--	--		--	
22 September	4	3.5	2.3	4.8	3.0	0		0		14.3	5.1	10.8	3.2	0		0	
29 September	4	1.8	1.1	1.5	0.7	0		0.3	0.3	17	7.7	9.3	2.6	0		0.5	0.3
10 October	4	1.8	0.9	2.3	1.3	0		0.3	0.3	3.8	2.5	3.3	1.6	0		0.5	0.3

Table 4. **Mean numbers of arthropods collected from hanging bottle refuges in apple orchards in 1996**

Date collected	No. of refuges	Earwigs				Other arthropods
		male		female		
		mean	SE	mean	SE	
16 July	9	0		1.3	0.5	0
26 July	8	0.9	0.5	2.9	2.3	0
3 September	16	14.2	3.6	31.3	1.0	0
12 September	12	0.1	0.1	0.8	0.3	0

Table 5. **Mean numbers of arthropods collected from hanging bottle refuges in pear orchards in 1996**

Date collected	No. of refuges	Earwigs				Other arthropods	
		male		female			
		mean	SE	mean	SE	mean	SE
16 July	8	0		0.5	0.3	0	
26 July	8	0.4	0.4	0.6	0.4	0.1	0.1
19 August	8	0.1	0.1	0.8	0.5	0.4	0.3
3 September	8	0.1	0.1	0.3	0.2	0	

Table 6. **Mean numbers of earwigs caught in stake and trunk bottle refuges in a pear orchard during 1994**

Date collected	Stake			Trunk		
	No. of refuges	mean	SE	No. of refuges	mean	SE
19 September	12	12.6	3.1	8	12.3	4.9
26 September	10	3.1	1.4	6	2.2	0.9
7 October	10	2.5	1.0	6	2.0	0.9

Table 7. **Total number of spiders extracted from forty four refuges situated in apple and pear orchards during 1994/95 winter**

	Total	male	female/ immature	query sex
Thomisidae	72	5	38	29
Theridiidae	512	106	334	72
Salticidae	1	0	0	1
Araneidae	4	0	2	2
Clubionidae	77	18	42	17
Linyphiidae	4	0	0	4

Table 8. **Total number of spiders extracted from one hundred and thirty refuges situated in apple and pear orchards during the 1995/96 winter**

	Total	male	female	immatures
Thomisidae	106			
Theridiidae	83	17	43	23
Salticidae	11	2	4	5
Araneidae	12	2	9	1
Clubionidae	22	8	12	2
Anyphaenidae	1	1	0	0
Linyphiidae	3	2	1	0

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JDF/AP:2.1.97