

# ALPHACYPERMETHRIN/FLUFENOXURON – A NEW HIGH PERFORMANCE RESIDUAL INSECTICIDE COMBINATION FOR COCKROACH CONTROL

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**Abstract**—A formulation consisting of the pyrethroid insecticide alphacypermethrin and flufenoxuron, an acylurea insect growth regulator, has been shown to give effective and persistent control of cockroach infestations after a single treatment. Flufenoxuron is a new high performance residual insecticide for public hygiene pest control which kills insects by interference with chitin formation. Failure of the chitin to develop properly results in the death of arthropods during ecdysis. Although not an adulticide, a high proportion of eggs laid by an adult after exposure to flufenoxuron are non-viable. Combining alphacypermethrin and flufenoxuron ensures both persistence and effective insecticidal activity at all stages of the pest life-cycle.

A one-pack mixture formulated as a suspension concentrate containing 60/30 g/l of alphacypermethrin/flufenoxuron was applied to give a deposit of 15.0/7.5 mg ai/m<sup>2</sup> in apartments infested with *Blattella germanica* and *Blatta orientalis*. The treatment gave rapid and extended control of both species (eradication by 1 month, maintained until the end of the trial at 13 months).

The level of alphacypermethrin was reduced to 30 g/l to give a 30/30 g/l SC alphacypermethrin/flufenoxuron mixture. This formulation was applied to give a deposit of 7.5/7.5 mg ai/m<sup>2</sup> in two further trials to apartments infested with *B. orientalis*. In the first trial, eradication was achieved in most apartments by 2 months post-treatment and throughout the trial site by 9 months post-treatment. This was maintained until the trial was terminated at 12 months. In the second of these trials, eradication was achieved by 9 months post-treatment in five of the six apartments treated, and was maintained until the end of the trial at 12 months. In the remaining apartment, 96.5% and 99.0% control was achieved by 9 and 12 months, respectively.

A further trial was carried out at a pig farm with a high *B. orientalis* infestation using the 30/30 g/l SC mixture applied to give a deposit of 7.5/7.5 mg ai/m<sup>2</sup>. An infestation at the farmhouse was reduced by 81% and 95% after 17 and 42 days post-treatment, respectively. Two re-infestations of the farmhouse were successfully controlled, the first by treatment of the pig unit nearest the house and the second, 409 days after the initial treatment of the farmhouse, by a second application which resulted in 98% control and eradication by 17 and 171 days post-treatment, respectively.

Using such a combination of insecticides with different modes of action should prove to be an effective management strategy to follow for professional cockroach control, particularly in situations where resistance is suspected.

## INTRODUCTION

Flufenoxuron is a new high performance residual insecticide developed by American Cyanamid for public hygiene pest control. It is an acylurea insect growth regulator (IGR) which causes death of insects and other arthropods during the moulting process between the various nymphal or larval stages. It acts by interfering with the deposition of chitin in the new cuticle during moulting, i.e. a chitin synthesis inhibitor (CSI). Flufenoxuron is highly specific and exhibits very low levels of acute toxicity to vertebrates, the rat oral LD<sub>50</sub> being >3000 mg/kg.

Although not an adulticide, a very high proportion of eggs laid by adults exposed to this insecticide are non-viable. This has been demonstrated (by the authors) in laboratory tests against *B. germanica*. Adults exposed to deposits of flufenoxuron at 10 mg ai/m<sup>2</sup>, in choice exposure residuality tests, produced non-viable and deformed egg pods. The majority of mortality during the tests occurred at the egg pod stage and during early nymphal instar moults. Work carried out against a range of CSI's (Koehler *et al*, 1989) also showed that control was effected mainly by non-development of egg pods and death of early-stage nymphs during ecdysis. It was suggested from these results that CSI's have potential for inclusion in integrated cockroach management programmes.

Field studies carried out (Reid *et al*, 1992) confirmed flufenoxuron at 0.033% and 0.066% ai (active ingredient) to be an effective IGR for German cockroach management programmes. It was

recommended that further field studies be carried out to determine if the concentration of flufenoxuron could be reduced further with no loss of efficacy. In our experience, results of field trials carried out with flufenoxuron at 0.015% ai demonstrated that the speed of action of this insecticide, when used alone, was unacceptably slow- 97% control achieved by 100 days after treatment.

Combining the high performance pyrethroid insecticide alphacypermethrin and the IGR flufenoxuron ensures both persistence and effective insecticidal activity at all stages of the pest life-cycle. The use of a mixture of a pyrethroid and an IGR insecticide also offers advantages regarding pest resistance management (Hemingway and Small, 1993; Williams, 1995).

This paper describes a series of field trials carried out to determine the efficacy of a 1-pack SC (suspension concentrate) mixture of alphacypermethrin and flufenoxuron against cockroaches. The studies were carried out at four sites, three of which were residential apartment blocks and the fourth a pig farm.

The trials in residential apartments were carried out with the help and co-operation of the local EHO's and PCO's.

## MATERIALS AND METHODS

### **Trial 1. Alphacypermethrin/flufenoxuron 60/30 g/l SC against *B. germanica* and *B. orientalis* in apartments**

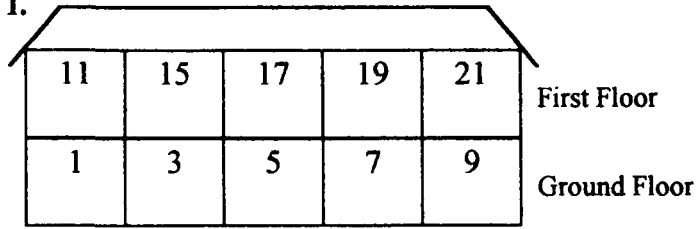
*Aim.* The aim of this trial was to determine the efficacy of an alphacypermethrin/flufenoxuron 60/30 g/l SC mixture applied at the rate of 15.0/7.5 mg ai/m<sup>2</sup> against both *B. germanica* and *B. orientalis*.

*Site.* The trial site consisted of a block of ten residential apartments (5 ground floor and 5 first floor) in Oldham, Greater Manchester (see Figure 1(a) for plan of site). The block was situated on an estate with a long history of recurring *B. germanica* and *B. orientalis* infestations. The apartments had interconnecting ducts supplying all services. The hot water heating was fed from a remote boiler house through to each apartment. The ducts and internal panelling were in poor condition throughout and general hygiene varied from good to poor, with food debris, oily deposits, overflowing waste bins and open food storage common. Some apartments were cluttered with furniture.

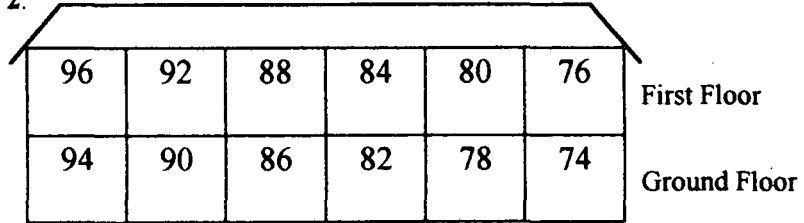
*Pre-treatment survey.* Two 'HOY HOY TRAP-A-ROACH' sticky cockroach traps were placed in each apartment, one in the kitchen gas meter cupboard and one in the bathroom behind the washbasin. Traps were left in place for six nights, except for one apartment, where they were removed after two nights as they were approaching trap saturation. The number of adults and nymphs present on each trap were counted and the species recorded. The population of each species was estimated for each apartment by calculating a 'Trap Index' (T.I.) i.e. the number of cockroaches trapped per trap per night. *B. germanica* and *B. orientalis* infestations were categorised according to the respective Trap Indexes for each apartment. These categories are shown in Table 1.

*Treatment.* The treatment followed the practical method routinely employed for cockroach control in apartments by the Local Environmental Health Authority. Three apartments, no's. 3, 5 and 11 had zero infestation and were not treated. All other apartments were treated. Alphacypermethrin/flufenoxuron 60/30 g/l SC was diluted with tap water (25 ml SC to 5l tap water) and applied as a coarse spray through a 5l 'Gloria' sprayer at 1.4–2.0 × 10<sup>5</sup> Pa. The target volume rate was 5 of spray per 100m<sup>2</sup>, equivalent to a deposit rate of 15.0/7.5 mg ai/m<sup>2</sup>. Approximately 50cm wide spray bands were applied to wall/wall, wall/floor and wall/ceiling interceptions, around door frames, within emptied cupboards and under beds and furniture. Spray was directed into accessible gaps in ducts, service pipes and panels. In the stairways and communal hallways, 50cm wide spray bands were applied to wall/wall, wall/floor and wall/ceiling interceptions. An external barrier was applied across the access to every apartment including the three untreated, uninfested apartments. The volume of spray, to the nearest litre, applied to each apartment was recorded. No treatment was applied to areas on which food was prepared or stored, or to cooking equipment.

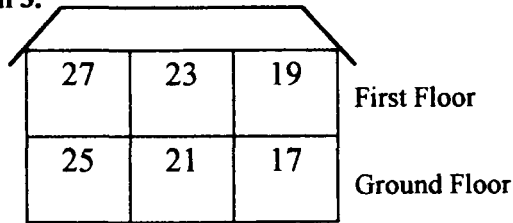
**1(a) Trial 1.**



**1(b) Trial 2.**



**1(c) Trial 3.**



**1(d) Trial 4.**

Treated areas are shown shaded.

— 5m

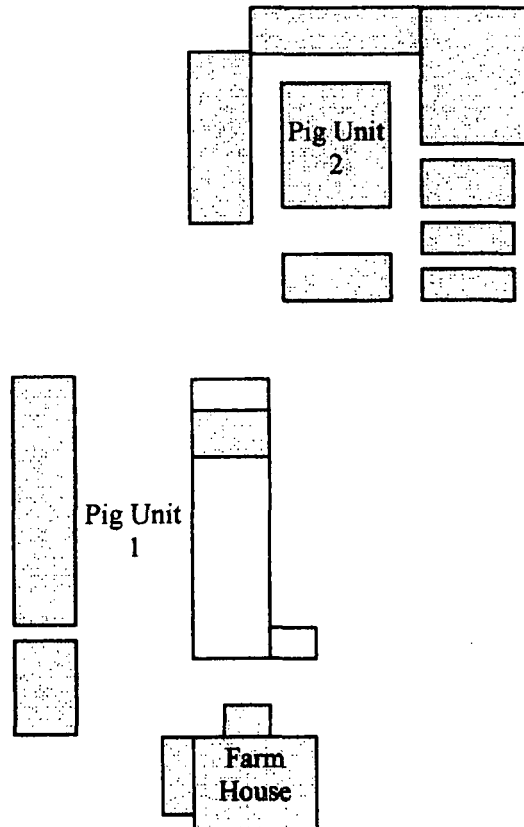


Figure 1. Site plans for trials 1 to 4

Table 1. Infestation categories for *B. germanica* and *B. orientalis*.

Category	Trap Index (T.I.)	
	<i>B. germanica</i>	<i>B. orientalis</i>
Low	>0–5.0	>0–1.0
Moderate	5.0–10.0	1.1–3.0
High	10.1–30.0	3.1–5.0
Very high	30.1+	5.1+

*Post-treatment assessments.* Post-treatment assessments were carried out approximately 1, 8 and 12 months post-treatment (MPT). Assessments of the cockroach populations in each treated apartment were made following the same method used in the pre-treatment survey. All post-treatment assessments consisted of a seven night trapping period, after which the Trap Index for each species in each apartment was calculated.

Percentage control (%C) for each treated apartment at each assessment was calculated as follows:

$$\% C = 100 - \frac{\text{Trap Index @ post-treatment assessment}}{\text{Trap Index @ pre-treatment survey}} \times 100$$

### Trial 2: Alphacypermethrin/flufenoxuron 30/30 g/ SC against *B. orientalis* in apartments

*Aim.* The aim of this trial was to determine if the level of alphacypermethrin in the mixture could be reduced with no loss of efficacy in the field. The mixture evaluated in this trial was alphacypermethrin/flufenoxuron 30/30 g/l SC.

*Site.* The trial site consisted of a block of 12 residential apartments (six ground floor and six first floor) in Manchester (see Figure 1(b) for plan of site). The block was situated on an estate with a long history of recurring *B. orientalis* infestations. As with the apartments in Trial 1, these also had interconnecting ducts to supply heating and water. There were three service rooms each containing a boiler room and a bin room. The general hygiene varied from good to poor.

*Pre-treatment survey.* This was carried out as in Trial 1, except that three traps were placed per apartment, one in the kitchen, one in the bathroom and one in the hot-tank cupboard. The pre-treatment survey consisted of a seven night trap.

*Treatment.* All apartments and service rooms were treated. Alphacypermethrin/flufenoxuron 30/30 g/lSC was diluted with tap water (25mlSC : 5 water) and was applied as a coarse spray through a 5 B&G sprayer at a pressure of  $1.4\text{--}2.0 \times 10^5$  Pa to give a deposit of 7.5/7.5 mg ai/m<sup>2</sup>. The treatment consisted of the application of a 50cm wide spray band to wall/floor interceptions around each room paying particular attention to cracks and crevices. It was not necessary to treat wall/wall or wall/ceiling interceptions or around doors as the only species present was *B. orientalis* which does not climb as readily as *B. germanica*. One apartment, received a re-treatment three months after the first for reasons discussed later. Wall/floor interceptions in stairways and communal hallways were also treated. An external barrier was applied across the access to each apartment. The volume of spray to the nearest litre, applied to each apartment, was recorded.

*Post-treatment assessments.* Post-treatment assessments were carried out in each treated apartment as in the pre-treatment survey at 0.5, 2, 3, 6, and 9 MPT. Percentage control in each apartment at each assessment was calculated as in Trial 1.

**Trial 3. Alphacypermethrin/flufenoxuron 30/30 g/ SC against *B. orientalis* in apartments**

*Aim.* As trial 2. This trial was carried out to confirm the results obtained in Trial 2.

*Site.* The site consisted of a block of six residential apartments (three ground floor and three first floor) in Manchester (see Figure 1(c) for plan). The apartments were similar in design to those in Trial 2. Again, hygiene varied from good to poor.

*Pre-treatment Survey.* As Trial 2.

*Treatment.* As Trial 2.

*Post-treatment assessments.* As Trial 2, except that post-treatment assessment visits were carried out 1.5, 3, 6, 9 and 12 MPT.

**Trial 4. Alphacypermethrin/flufenoxuron 30/30 g/l SC and alphacypermethrin 60 g/l SC against *B. orientalis* at a pig farm.**

*Aim.* This trial was carried out at a pig farm. This site was selected to evaluate the performance of the alphacypermethrin/flufenoxuron 30/30 g/l SC mixture under exceptionally severe conditions and to demonstrate the contribution of flufenoxuron in a situation where commercially available conventional treatments would rapidly fail. Again, the pest species present was the more difficult to control *B. orientalis*.

*Site.* The trial site consisted of a farmhouse and two pig units (See Figure 1 (d) for site plan). The farmhouse was a three bedroom semi-detached house. The hygiene in the house was good, but many harbourages were available in the fabrication and fittings. Conservatories had been added to the side and rear doorways.

The pig unit nearest the house (Unit 1) consisted of two weaner houses and a row of fattening pens. Adjacent buildings contained equipment and feed. The pig unit furthest from the house (Unit 2) consisted of eight buildings containing fattening pens. A store piled high with stale bread and other feed was adjacent to this unit. Each unit had individual slurry pits. Construction of the units was concrete raft on rubble core and corrugated tin walls and roofs clad with hardboard with fibreglass insulation. Pen construction was of concrete blocks with many cavities. Some units had been re-roofed on top of old roofing. Both units were extensively soiled with organic material and dust and provided many harbourages and a constant food supply for cockroaches. With the exception of the weaner houses no heating was supplied but internal temperatures remained above ambient due to the radiation of animal body heat.

The trial site had a long history of continuous infestation by *B. orientalis* which had never been treated. Considerable populations were present throughout the year in the pig units and farm. The cockroaches were visible outside the buildings from early spring to late autumn suggesting possible movement between buildings.

*Pre-treatment surveys.* This was carried out using sticky traps as in Trial 1. Five traps were placed in the farmhouse (two in the kitchen, one in the lounge, one by the gas meter and one in the main bedroom) for four nights prior to each treatment. In pig units 1 and 2 a total of 20 and 30 traps respectively were placed for seven nights prior to each treatment. Trap positions were selected to be inaccessible to the pigs. All trap positions were kept constant throughout the trial.

*Treatments.* In the farmhouse alphacypermethrin/flufenoxuron 30/30 g/lSC was applied as in Trial 2. Each room and both conservatories were treated. A second application was carried out 13.5 months later. This treatment also included a 1m wide barrier which was applied around the accessible perimeter of the farmhouse.

*Pig Unit 1:* Alphacypermethrin/flufenoxuron 30/30 g/lSC was applied to give a deposit of 7.5/7.5 mg ai/m<sup>2</sup>, as in Trial 2, except that application was restricted to the wall/ceiling interceptions and

upper wall/wall interceptions of the units and to cracks and crevices. This was to ensure that there was no contact with the animals or their feed and to prevent slurry contamination. A 1m wide barrier was applied to the accessible perimeter of the buildings.

*Pig Unit 2:* Alphacypermethrin 60 g/lSC was diluted with tap water (12.5ml to 5l water) and was applied to give a deposit of 7.5 mg ai/m<sup>2</sup> following the method used in Unit 1. This application was carried out to demonstrate the effect of an alphacypermethrin treatment under severe conditions. Eleven weeks later, alphacypermethrin/flufenoxuron 30/30g/lSC was applied to give a deposit of 7.5/7.5 mg ai/m<sup>2</sup>, as in Unit 1.

*Post-treatment assessments.* Post-treatment assessments were carried out at several time intervals following each treatment. Traps were left in position for 6–10 night periods. Trap indexes and percentage control were calculated as in previous trials.

For areas which received two applications the final post-treatment assessment for the first application formed the pre-survey for the second treatment.

## RESULTS

### Trial 1. Alphacypermethrin/flufenoxuron 60/30 g/lSC against *B. germanica* and *B. orientalis* in apartments.

*Pre-treatment survey.* Pre-treatment survey trap numbers and Trap Indexes are shown in Table 2. Apartments 3, 5 and 11 had no infestation present. Apartment 1 had a high infestation of *B. germanica*, 7 and 21 had a low infestation of *B. orientalis* and apartments 9, 15 and 19 had moderate infestations of *B. orientalis*. Both species were present, at a moderate level, in apartment 17.

*Treatment.* Treatment was only applied to infested apartments. All rooms were treated in apartment 1 which had a high *B. germanica* infestation and the total volume of spray applied was 8l. In all other infested apartments, treatment was only applied to the kitchen, toilet room and bathroom and the total volume of spray applied to each apartment was 4l. During the applications there was considerable flushing of *B. germanica* within 10 minutes of spraying in numbers 1 and 17. Flushing of *B. orientalis* also occurred in apartment 17.

*Post-treatment assessments.* The results of the post-treatment assessments are shown in Table 2. All trap counts were zero at the first post-treatment assessment and remained at zero through to termination of the trial after a year- 100% control throughout.

Table 2. Pre-treatment survey and post-treatment assessment results of Trial 1: Alphacypermethrin/flufenoxuron 60/30 g/ SC against *B. germanica* and *B. orientalis*.

Apartment	Species present	Pre-treatment Survey		Post-treatment Assessments, at months post-treatment (MPT)					
		No. trapped	T.I.	1 MPT		8 MPT		12 MPT	
				T.I.	% Control	T.I.	% Control	T.I.	% Control
1	<i>B. germanica</i>	137	22.83	0.0	100.0	0.0	100.0	0.0	100.0
7	<i>B. orientalis</i>	2	0.17	0.0	100.0	0.0	100.0	0.0	100.0
9	<i>B. orientalis</i>	19	1.16	0.0	100.0	0.0	100.0	0.0	100.0
15	<i>B. orientalis</i>	17	1.42	0.0	100.0	0.0	100.0	0.0	100.0
17	<i>B. germanica</i>	64	5.33	0.0	100.0	0.0	100.0	0.0	100.0
17	<i>B. orientalis</i>	34	2.83	0.0	100.0	0.0	100.0	0.0	100.0
19	<i>B. orientalis</i>	10	0.83	0.0	100.0	0.0	100.0	0.0	100.0
21	<i>B. orientalis</i>	3	0.25	0.0	100.0	0.0	100.0	0.0	100.0

**Trial 2. Alphacypermethrin/flufenoxuron 30/30 g/l SC against *B. orientalis* in apartments.**

*Pre-treatment survey.* Pre-treatment survey trap numbers and Trap Indexes are shown in Table 3. Apartments 80 and 96 and two of the three service rooms were not infested. These, although treated along with the other apartments, were not included in the rest of the study. Apartment 90 presented major problems regarding access. No access could be gained for a pre-treatment survey, but access was gained for treatment. During the treatment it became obvious from the distribution and the number of insects present that this was the probable source of the infestation. Apartments 78, 82, 86, 94 and the services adjacent to 86 had low infestations of *B. orientalis*. Apartments 76 and 92 had moderate *B. orientalis* infestations and apartments 88 and 74 had high and very high *B. orientalis* infestations, respectively.

*Treatment.* Treatment was applied to all twelve apartments. All rooms were treated, and the total volume of spray applied per apartment was 2.5ℓ.

*Post-treatment assessments.* The results of the post-treatment assessments are shown in Table 3. Unfortunately no further access could be gained to apartment 90, and therefore the effect of the treatment on this apartment could not be directly monitored. By 2 MPT 100% control had been achieved in all apartments except numbers 88, 92 and 94 where 70.5, 77.6 and 96.6% control, respectively, was achieved.

By 3 MPT control appeared to be starting to fail, 100% only being maintained in apartments 74, 82 and 94. Apartments 76, 78 and 92 had 96.0, 92.3 and 85.8% control, respectively. However in apartments 88, 86 (beneath 88) and the services adjoining 86 the trap indexes indicated less than 50% control. It was discovered that apartment 88 had been vacated since the 2 MPT visit. The apartment had been totally re-decorated throughout and the carpets replaced. Most, if not all, of the insecticide deposit had therefore been removed and this apartment (which had an initial high infestation) was providing an untreated harbourage. This apartment was re-treated immediately after this was discovered following the 3 MPT assessment.

By 9 MPT 100% control had been achieved throughout the site, and this was maintained to 12 MPT when the trial was terminated.

**Trial 3. Alphacypermethrin/flufenoxuron 30/30 g/l SC against *B. orientalis* in apartments.**

*Pre-treatment survey.* Pre-treatment survey trap cockroach numbers and Trap Indexes are shown in Table 4. All six apartments were infested with *B. orientalis*, apartments 17, 19, 23 and 27 had low infestations and apartments 21 and 25 had high infestations.

*Treatment.* Treatment was applied to all six apartments. All rooms were treated, and the total volume of spray applied per apartment was 2.5ℓ.

*Post-treatment assessments.* The results of the post-treatment assessments are shown in Table 4. The mean percentage control of cockroaches in apartments by 1.5 and 3 MPT were 73.7 and 84.8% respectively. By 6 MPT 100% control was achieved in apartments 17, 19 and 21. In apartments 23, 25 and 27 there was 95.2, 88.1 and 55.5% control, respectively. Apartment 25 had the highest pre-treatment infestation and appeared to be the source of the infestation for the whole block. Apartment 27 was situated directly above 25 and apartment 23 was adjacent to 27. By 9 MPT 100% control was achieved in all apartments except 25, where 96.5% control was recorded. By 12 MPT 100% control had been maintained in all apartments except number 25 in which two first instar nymphs were trapped reducing control in that apartment to a level of 99.0%.

**Trial 4. Alphacypermethrin/flufenoxuron 30/30 g/l SC and alphacypermethrin 60 g/l SC against *B. orientalis* at a pig farm.**

*Pre-treatment surveys.* *B. orientalis* was the only species present at this site. At the farmhouse a total of 21 cockroaches were trapped (T.I.=1.05) during the first pre-treatment survey. During the second

Table 3. Pre-treatment survey and post-treatment assessment results of Trial 2: Alphacypermethrin/flufenoxuron 30/30 g/l SC against *B. orientalis*.

Apartment	Pre-treatment survey		Post-treatment assessments, at months post-treatment (MPT)											
	No. trapped	T.I.	0.5 MPT		2 MPT		3 MPT		6 MPT		9 MPT		12 MPT	
			T.I.	% Control	T.I.	% Control	T.I.	% Control	T.I.	% Control	T.I.	% Control	T.I.	% Control
74	80	8.88	0.14	98.4	0.00	100.0	0.00	100.0	0.05	99.5	0.00	100.0	0.00	100.0
76	25	1.19	0.10	92.0	0.00	100.0	0.05	96.0	0.00	100.0	0.00	100.0	0.00	100.0
78	13	0.62	0.14	77.4	0.00	100.0	0.05	92.3	0.05	92.3	0.00	100.0	0.00	100.0
82	1	0.05	0.00	100.0	0.00	100.0	0.00	100.0	0.05	0.0	0.00	100.0	0.00	100.0
86	4	0.19	0.86	0.0	0.00	100.0	0.10	50.0	0.00	100.0	0.00	100.0	0.00	100.0
88	69	3.29	no access		0.97	70.5	2.90	11.9	Re-treated due to re-decoration of apartment, see below					
92	49	2.33	1.05	55.0	0.52	77.6	0.33	85.8	0.14	93.9	0.00	100.0	0.00	100.0
94	18	0.86	0.95	0.0	0.03	96.6	0.00	100.0	0.00	100.0	0.00	100.0	0.00	100.0
Service room	7	1.00	1.43	0.0	0.00	100.0	0.78	22.0	0.00	100.0	0.00	100.0	0.00	100.0

Apartment	Pre-2nd treatment survey		Reason for re-treatment	Post-treatment assessments, at months post-treatment (MPT)										
	No. trapped	T.I.		1 MPT		3 MPT		6 MPT		9 MPT		12 MPT		
			T.I.	% Control	T.I.	% Control	T.I.	% Control	T.I.	% Control	T.I.	% Control		
88	61	2.90	Flat re-decorated		0.62	78.6	0.29	90.0	0.00	100.0	0.00	100.0	0.00	100.0

Table 4. Pre-treatment survey and post-treatment assessment results of Trial 3: Alphacypermethrin/flufenoxuron 30/30 g/l SC against *B. orientalis*.

Apartment	Pre-treatment survey		Post-treatment assessments, at months post-treatment (MPT)									
	No. trapped	% T.I.	1.5 MPT		3 MPT		6 MPT		9 MPT		12 MPT	
			T.I.	% Control	T.I.	% Control	T.I.	% Control	T.I.	% Control	T.I.	% Control
17	3	0.110	0.000	100.0	0.000	100.0	0.000	100.0	0.000	100.0	0.000	100.0
19	2	0.070	0.036	50.0	0.046	50.0	0.000	100.0	0.000	100.0	0.000	100.0
21	111	3.960	0.360	90.9	0.050	99.0	0.000	100.0	0.000	100.0	0.000	100.0
23	7	0.250	0.036	85.6	0.036	85.6	0.048	95.2	0.000	100.0	0.000	100.0
25	113	4.040	1.620	60.0	1.047	74.0	0.480	88.1	0.140	96.5	0.040	99.0
27	3	0.090	0.040	55.5	0.000	100.0	0.036	55.5	0.000	100.0	0.000	100.0



pre-treatment survey a total of 28 cockroaches were trapped (T.I.=1.40). The infestation in the house was categorised as moderate prior to each treatment.

In Unit 1, during the pre-treatment survey, a total of 655 cockroaches were trapped (T.I. = 4.92). This infestation was categorised as high.

In Unit 2, 1155 (T.I.=6.88) and 873 (T.I.=5.42) cockroaches were trapped during pre-treatment surveys 1 and 2, respectively. The infestation in Unit 2 was categorised as very high in both instances.

Some traps in the pig units were saturated with cockroaches and therefore Trap Indexes represent an under-estimate of the pre-treatment populations.

**Treatments.** During both applications 5ℓ of formulation was applied inside the farmhouse. During the second application only, a further 2ℓ of formulation was applied as an external barrier, around the perimeter of the house.

A total of 26ℓ of formulation was applied to Unit 1.

In Unit 2, during the first application, a total of 40ℓ of alphacypermethrin 60 g/ℓ SC was applied. During the second application a total of 40ℓ of the alphacypermethrin/flufenoxuron mixture was applied.

No flushing of cockroaches occurred during the farmhouse applications, but considerable flushing occurred in both units within 20 minutes of spraying.

**Post-treatment applications.** Farmhouse: After the first treatment 81.0 and 94.3% control was achieved by 0.5 and 1.5 MPT, respectively (See Figure 2). By 2.5 MPT control had reduced to 72.4% and it was evident that minor re-infestation of the house was occurring from adjacent Unit 1 which was not yet treated (Unit 1 was treated 11 weeks after the first treatment of the farmhouse). Following the treatment of Unit 1, percentage control in the farmhouse increased to 97.1% and 100% by 5 and 7 months after the first treatment of the house. This was maintained until 9.5 MPT. A major re-infestation of the farmhouse had occurred by 13.5 MPT concurrent with control breakdown in Unit 1. After the second treatment of the farmhouse, which this time included an external barrier treatment, 97.9, 91.4 and 100% control was achieved 0.5, 2.5 and 5.5 months after the second treatment, respectively.

In Unit 1 greater than 80% control was achieved up to 4 MPT and this declined to 48% by 10.5 MPT. (See Figure 3).

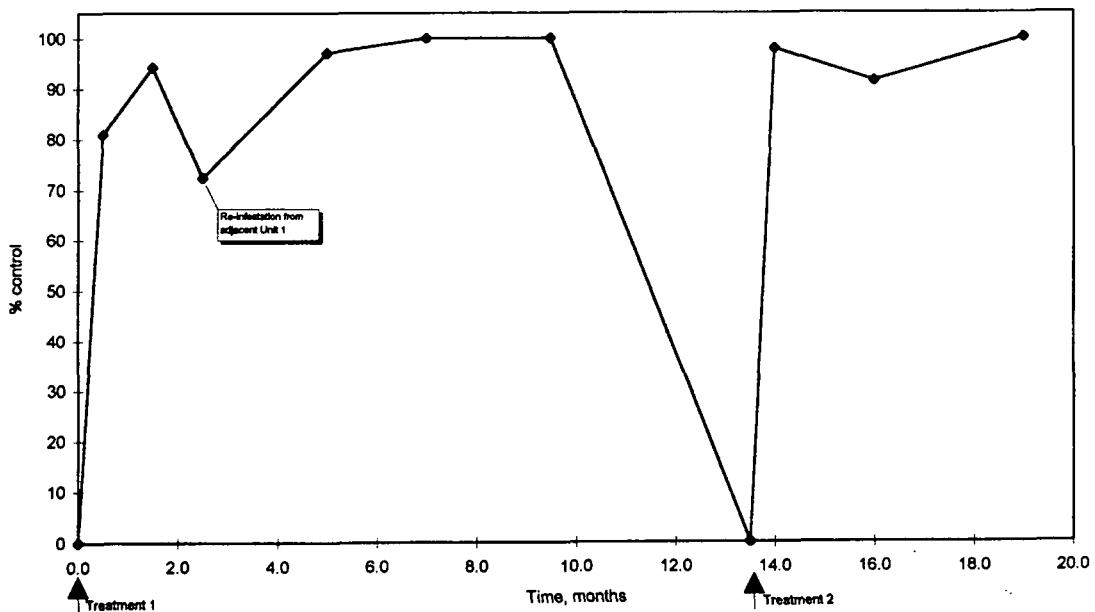


Figure 2. Trial 4: Field trial of alphacypermethrin/flufenoxuron 30/30g/ℓ SC applied at the rate of 7.5/7.5 mg ai/m<sup>2</sup> against *B. orientalis* at a farmhouse.

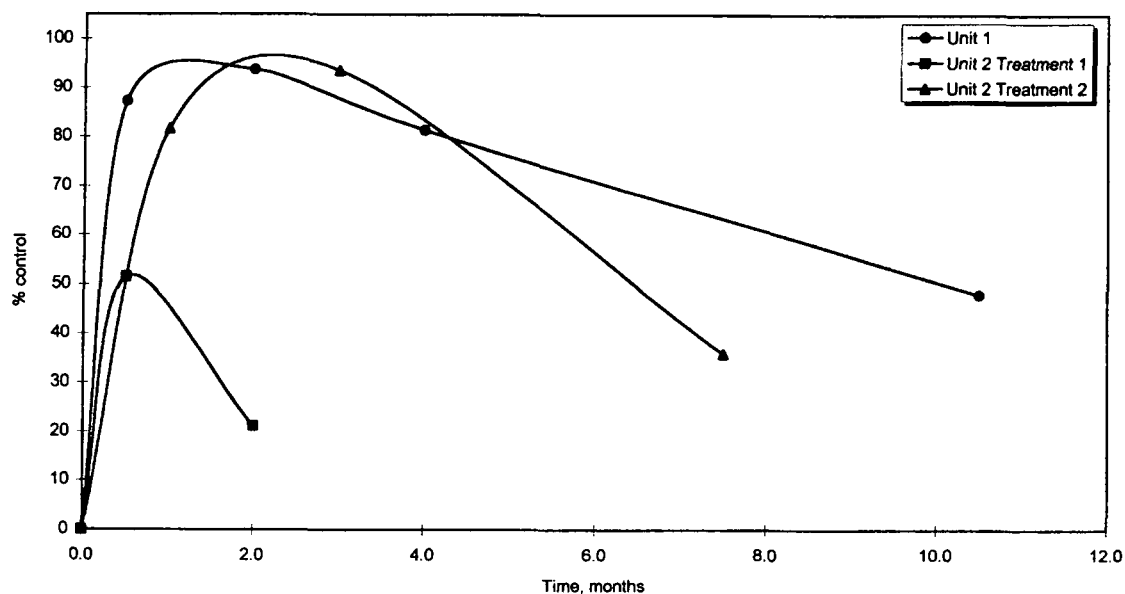


Figure 3. Field trials of alphacypermethrin alone and an alphacypermethrin/flufenoxuron mixture in commercial pig units against *B. orientalis*.

Unit 1: Alphacypermethrin/flufenoxuron 30/30g/l SC applied at rate of 7.5/7.5 mg ai/m<sup>2</sup>.

Unit 2: Treatment 1: Alphacypermethrin 60g/l SC applied at rate of 7.5 mg ai/m<sup>2</sup>.

Unit 2: Treatment 2: Alphacypermethrin/flufenoxuron 30/30g/l SC applied at the rate of 7.5/7.5 mg ai/m<sup>2</sup>.

The first application to Unit 2, which was alphacypermethrin 60g/l SC applied to give 7.5 mg ai/m<sup>2</sup>, effected only 51.5% control by 0.5 MPT (See Figure 3). This had dropped to 21.2% by 2 MPT indicating control failure. Following the second application to Unit 2, which was the mixture applied to give 7.5/7.5 mg ai/m<sup>2</sup>, 81.6 and 93.5% control was achieved by 1 and 3 MPT, respectively. The population gradually recovered, however, and control had decreased to only 35.8% by 7.5 MPT.

## DISCUSSION

This series of field trials clearly demonstrates the excellent efficacy of the 1-pack alphacypermethrin/flufenoxuron combination against both *B. germanica* and *B. orientalis* in typical and extreme public health and agricultural situations. The main advantages offered to the professional user by this combination are those of a rapid speed of action, ease of application, persistence (especially under adverse conditions) and the potential for use in resistance management strategies.

A typical application of alphacypermethrin applied to give a deposit of 30mg ai/m<sup>2</sup> would be expected to give greater than 98% control of cockroaches within 14 days of treatment with around 90 days persistence. The author's past experience of field trials carried out with flufenoxuron alone applied to give a deposit of 7.5 mg ai/m<sup>2</sup> against *B. germanica* in apartments gave 97% control 100 days after treatment with at least 580 days persistence (end of trial). The slower speed of action of flufenoxuron alone would be unacceptable, as a rapid and visible reduction in pest numbers is expected in pest control, especially in domestic and public situations. If cockroaches are still visible months after a treatment (even though control is being achieved) it would usually result in a call-back for re-treatment.

The combination of alphacypermethrin/flufenoxuron 60/30 g/l SC, applied to give 15.0/7.5 mg ai/m<sup>2</sup> in Trial 1, demonstrated the rapid speed of action typical of alphacypermethrin together with the extended persistence of flufenoxuron. In this trial, 100% control was achieved by 1 MPT and was maintained until the end of the trial at 12 MPT, even though surrounding apartment blocks were infested. Post-trial trapping of this site has indicated that the block remains uninfested several years later.

Trials 2 and 3 demonstrated that by reducing the level of alphacypermethrin to 30 g/l, and the mixture applied to give a deposit of 7.5/7.5 mg ai/m<sup>2</sup>, excellent and persistent control was still achieved in typical and extreme public health situations.

This reduced deposit rate even controlled *B. orientalis*, which is notoriously more difficult to control with IGR's than *B. germanica*, due to its longer life-cycle, long egg-pod stage and higher chitin content. The treatment of *B. orientalis* infestations with conventional insecticides usually requires a follow-up treatment especially as the egg-pods may take up to 3 months (at 20°C) to hatch (Le Patourel, 1993). *B. orientalis* egg-pods are often described as "time-bombs", and unless a re-treatment is carried out to kill newly emerged nymphs, re-infestation will occur (Burgess, 1990). In Manchester, a regime routinely followed for cockroach control by the Local Authority involves a dust and a spray treatment in each apartment. This is followed-up by a re-treatment visit several weeks later when further dust and spray treatments are carried out. Thus, in total, each apartment receives four treatments. The alphacypermethrin/flufenoxuron combination requires only one limited area band (0.5m wide) and crack and crevice application to give control and persistence.

Re-infestation not only occurs by the hatching of egg-pods, but also by insect migration. Studies have shown that *B. orientalis*, when displaced from preferred harbourages, can live for long periods under conditions which are sub-optimal for population growth and reproduction before re-infesting optimal sites within buildings. This species could possibly overwinter outdoors in much of Western Europe provided they can locate frost-free harbourages (Le Patourel, 1993). Migration occurred during these studies, in Trial 4, when cockroaches from the adjacent pig units re-infested the farmhouse. It was shown that in a situation where the surrounding cockroach population is very high, the alphacypermethrin/flufenoxuron mixture is effective, providing that an adequate external barrier treatment is also applied.

In socially deprived areas such as those encountered in Trials 1–3, re-infestation commonly occurs when second-hand furniture is moved from infested apartments to uninfested apartments or blocks. A family moving house may, without realising, move their cockroach infestation in their furniture with them to their new home. If that new home happens to be an apartment in a block, the infestation will soon spread. The results reported here show that the alphacypermethrin/flufenoxuron combination should prevent such re-infestation from occurring.

Poor access to apartments is an on-going problem faced by PCO's in cockroach control. Untreated harbourages are probably therefore common in treated blocks. The importance of a thorough treatment to remove potential harbourages was clearly shown during Trial 2. Apartment 88 which initially started with a high infestation became vacant between 2 and 3 MPT. Carpets had been replaced and the entire flat redecorated, removing most, if not all of the insecticide deposit. This flat therefore provided an untreated harbourage for the cockroaches, and was beginning to effect what was initially perceived as control failure throughout the block as cockroaches migrated to adjoining apartments. Re-treatment of apartment 88, however, resulted in control being rapidly regained throughout the whole block.

In order to overcome the problem of re-infestation, whether caused by egg-pod hatch or by migration, a cockroach control treatment must be adequately persistent. The inclusion of flufenoxuron in the combination ensures this persistence.

The first three trials demonstrated the efficacy of the alphacypermethrin/flufenoxuron combination against both *B. germanica* and *B. orientalis* under typical public health conditions. Trial 4, however, was an extreme test for the formulation as the conditions in the pig units were far more severe than those normally encountered in public health applications for cockroach control. The persistence of CSI's under such adverse conditions offer advantages where conventional treatments would rapidly fail. The comparison of the alphacypermethrin alone treatment with that of the alphacypermethrin/flufenoxuron mixture, carried out in the pig units, clearly demonstrated the positive contribution of flufenoxuron to the combination. Under these extreme conditions the combination achieved much higher levels of control and far greater persistence.

Adverse conditions also occur in situations where control of urban insect pests is required. For example, a temperature of 45°C and humidity of 95% were recorded in a UK hospital underground service duct conditions which are highly conducive to the proliferation of pests, but degrade pesticides rapidly (Edwards, 1993). The alphacypermethrin/flufenoxuron combination should easily out-perform the more conventional treatments in conditions such as these.

A major advantage offered by the alphacypermethrin/flufenoxuron combination is the potential for use in resistance management strategies. Significant levels of resistance of *B. germanica* to pyrethroids already exist in the UK in the London area. Out of nine strains studied, eight had resistance levels greater than x10 (Chapman *et al*, 1995). A pyrethroid resistance management strategy would be to use a synthetic pyrethroid/IGR combination, particularly where multiple resistance mechanisms occur. The fast acting pyrethroid controls the majority of the population, resulting in rapid perceived control, while the highly resistant remainder of the population which survive are controlled by the IGR (Hemingway and Small, 1993).

In summary, the alphacypermethrin/flufenoxuron combination is the ideal product for the professional user. It is easy to apply and extremely efficient at controlling cockroaches in typical public health situations. The formulation offers excellent persistence even when used in adverse physical conditions. Finally, the combination offers potential for use as an effective resistance management strategy where resistance to pyrethroids is suspected.

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