THE APPLICATION OF ADVANCED WATER BASED TECHNOLOGY IN THE CONTROL OF PUBLIC HEALTH AND HYGIENE INSECT PESTS

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Abstract—Patented Film Forming Aqueous Spray Technology or 'FFAST' has been used to develop AquaPy®, a water based product containing synergised pyrethrins for use in the control of public health and hygiene pests. This product is highly flexible and can be applied undiluted through Ultra Low Volume (ULV) sprayers, or can be diluted with water for use in mist generators, thermal foggers or compression sprayers for surface applications. One of the major advantages of this formulation over existing pyrethrin containing products is the extremely low mineral hydrocarbon content which makes it ideally suited for use in food handling areas and in commodity stores, such as tobacco bonds.

When applied indoors as a ULV in large scale trials against a wide range of stored product and hygiene insects, the biological performance of this water-based formulation was at least equivalent and often superior to comparable oil based products.

Field trials were also conducted against infestations of *Blattella germanica*. Application of water diluted product as a surface spray gave good flushout and knockdown, and rapidly achieved control, with insect numbers falling by 97% within one day. However, due to the short persistence of pyrethrins cockroach numbers had increased to 33% of pre-treatment levels after 54 days. Control was maintained for over 90 days following re-treatment with AquaPy applied alongside slower acting hydramethylon gel baits. These results demonstrate how this formulation can be used in an integrated approach, making it ideal for use in insecticide sensitive locations.

INTRODUCTION

Insecticidal space spraying offers a convenient, flexible and rapid method for treating large outdoor areas for the control of flying insect pests and vectors of disease such as mosquitoes and houseflies. This method is also used extensively in the indoor control of both flying and crawling insects in situations ranging from small scale domestic applications to large scale industrial premises such as food and commodity storage facilities.

The majority of currently available space spray formulations are oil based. These are either supplied ready to use or can be diluted to the required concentration with further addition of oil, usually as mineral oil or diesel. While these oil based formulations have a long and established history of use, they have many disadvantages, including the risk of flammability during storage and in use, relatively high diluent and transport costs, odour, tainting of foodstuffs and the possibility of damage to exposed paintwork.

The use of water as a diluent largely overcomes these shortfalls. Emulsifiable concentrates (ECs) are oil based formulations that are compatible with water and form relatively stable emulsions that can be sprayed through conventional equipment. However the rapid evaporation of water that occurs from the spray droplets once they are formed often reduces their biological effectiveness, as they are less likely to impact on the target insect.

Extensive laboratory and field trials have been conducted to evaluate the potential of long chain alcohols, when incorporated into water based formulations. These demonstrated that water loss could be reduced with the result that space spray droplets remained within an effective size range. This in turn resulted in a corresponding improvement in biological performance compared with a conventional EC (Groome *et al.*, 1989, Slatter *et al.*, 1993). These successes led to the development of a range of patented water based space spray products primarily designed for outdoor use against houseflies and mosquitoes (European Patent No. 0 331 474). This formulation technology is often referred to by the acronym FFAST, for Film Forming Aqueous Spray Technology.

More recently a pyrethrins based FFAST formulation has been developed, primarily for use indoors, as a space and surface spray. While the evaporation retardation characteristics of this

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formulation are only expressed when applied as a space spray, the flexibility of this formulation type also allows its use as a surface spray.

This paper describes the results of various experiments to evaluate the performance of this formulation under conditions of normal use.

MATERIALS AND METHODS

Space spray trials

Formulations (applied undiluted)

Water based Product

	w/w
Natural Pyrethrins	6 % (from 50% extract, equivalent to 3% pure pyrethrins)
Piperonyl Butoxide	15 %
Surfactants	6 %
Vegetable oil	4.5 %
Long chain alcohol	1.5 %
De-ionised water	66.9 %
Uvitex fluorescent tracer	0.1 %

This particular FFAST formulation is currently marketed in the U.K. as AquaPy®.

Oil based Product

	w/v
Natural Pyrethrins	8 % (from 25% extract, equivalent to 2% pure pyrethrins)
Piperonyl Butoxide	16 %
Hydrocarbon solvent	75.9 %
Uvitex fluorescent tracer	0.1 %

This conventional oil based ready to use formulation served as a commercial standard.

Equipment

Fontan Turbostar 'E' fan assisted ULV generator (trolley mounted).

Normal phase high performance liquid chromatography (HPLC) using a silica column and UV detector system. This was used to determine pyrethrins content of solvent washings taken from deposit samplers.

Solex SL-200 digital lux meter.

Aluminium foil deposit samplers (15 x 6.5 cm), placed next to each insect location. Uvitex or pyrethrins levels were determined from solvent washings of these samplers.

Berkeley Controls quartz crystal microbalance (QCM), 10 stage cascade impactor, located 1 m above the ground, in the centre of the treatment area. This instrument has a sampling rate of 250 ml/minute, and determines size distribution by calculating droplet mass median diameter (MMD).

Casella AFC 123 personal air samplers. These draw air at 2.0 l/minute through a 0.8 μm pore cellulose nitrate filter and were used to measure aerial concentrations of uvitex, and thus by calculation, pyrethrins. Samplers were located in the centre of the treatment area, 3.5 m above floor level.

Perkin Elmer LS2 filter fluorimeter, used to determine levels of uvitex tracer.

Insects

Trials were conducted against a wide range of susceptible strain public health and stored product insect pests. Houseflies, mosquitoes and stored product moths were held in netting covered cages.

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Cockroaches and stored product beetles were placed in open, PTFE coated shallow plastic dishes. Tobacco beetles were restrained in dishes covered with a netting closure. All species were placed at each of 10 separate locations throughout the site, with flying insects suspended 1.5 m above ground, while crawling insects were placed on the floor.

Site

The trials site consisted of two self contained warehouses, 13,000 and 5,600 m^3 in volume and 7 m in height. These held large pieces of commodity storage and processing machinery. Temperature could be controlled and was maintained at 20±4°C. Fluorescent tubes provided the sole source of lighting.

Treatment regime and application rates.

The spray time for each formulation through the Turbostar was estimated from previous calibrations. A route that allowed the sprayer to cover the majority of the warehouse in the time required for the minimum dose rate was then determined. This route was used in all treatments with the number of circuits adjusted according to dose rate. Prior to each spray treatment the building was sealed and insects and aluminium deposit samplers placed in position. The appropriate amount of either water or oil based product was then dispensed into the Turbostar formulation reservoir and spraying initiated, with the machine following the prescribed route. The building remained sealed for 3 hours following application, and was ventilated thoroughly before the next treatment. Each product was applied at 1, 2 and 4 mg/m^3 pure pyrethrins, with two treatments conducted, one in each warehouse, at each dose rate.

Surface spray trials

Formulations

Pyrethrins water based FFAST formulation, as above. This was diluted 1 part in 39 parts water to give a solution containing 0.075% w/v pyrethrins.

350 g cartridges of cockroach gel bait containing 1.90 % w/w pure hydramethylnon (Maxforce®).

Equipment

10 litre compression sprayers fitted with 50 cm lance and 90° flat fan even spray nozzles for band spray application.

Site

The site, which was based in the U.K., consisted of a large industrial kitchen and dining room with associated food preparation and storage areas. The entire complex was heavily infested with *Blattella germanica*. Separate, laboratory based tests had previously established that this population had a low level of resistance (×5) to pyrethroids.

Population monitoring and insecticide application

The cockroach population was monitored at regular intervals both before and after insecticidal treatments using Hoy Hoy sticky traps (Earth Chemical Company). Up to 18 traps were placed throughout the site in typical harborage areas and left down overnight at each monitoring interval. The site was initially treated with water diluted formulation applied as a band spray to likely cockroach harborages in the conventional manner and at an approximate rate of 5 litres per 100 m^2. This is equivalent to a surface deposit of 37.5 mg/m^2 (pure) pyrethrins. Monitoring

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continued until 54 days after treatment at which point the site was once again sprayed at the same pyrethrins application rate. This was followed immediately with an application of hydramethylnon gel, placed at a rate approximately equivalent to 1 g gel/m^2. Population monitoring continued at intervals for a further 92 days.

RESULTS

Space spray trials

Biological data

Results presented on Figure 1 demonstrate that the water based formulation was highly effective against all the flying insect species tested, and was equivalent to the oil based product, giving 100% kill of all species at 1 mg/m^3 pyrethrins. Against stored product beetles and cockroaches the water based formulation also gave consistently better kills (Figures 2 and 3).

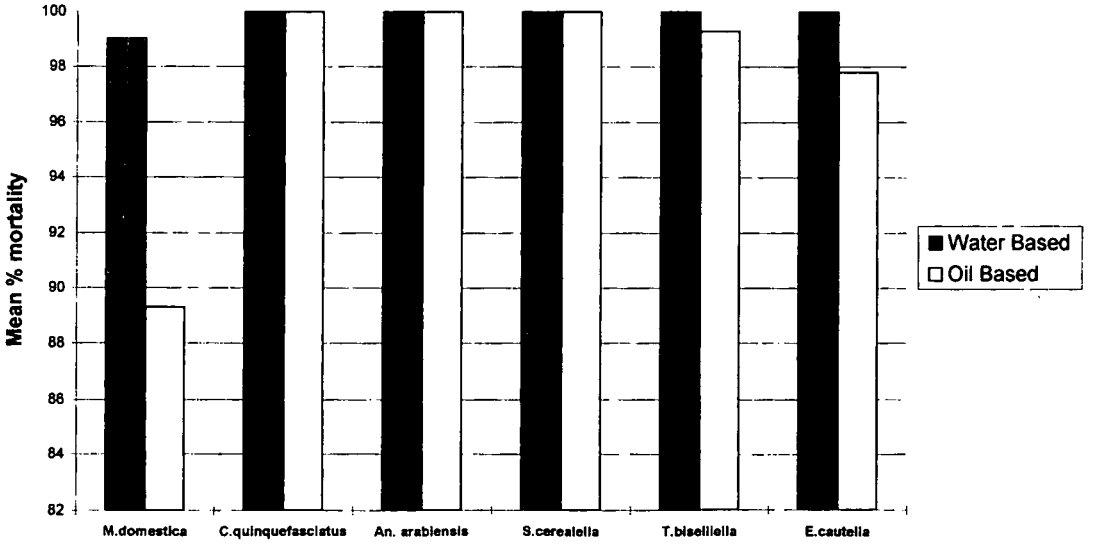

Figure 1. Warehouse trials – water and oil based formulations applied as ULV aerosols at 1 mg/m^3 pyrethrins against flying insect species.

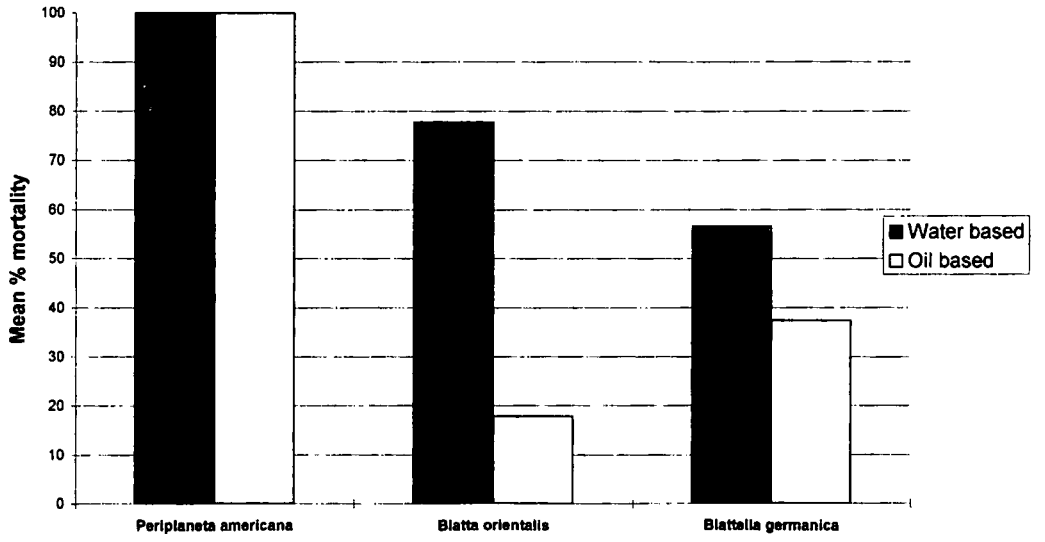

Figure 2. Warehouse trials – comparative performance of water and oil based formulations against cockroaches. Both products applied as a ULV aerosol at 2 mg/m^3 pyrethrins.

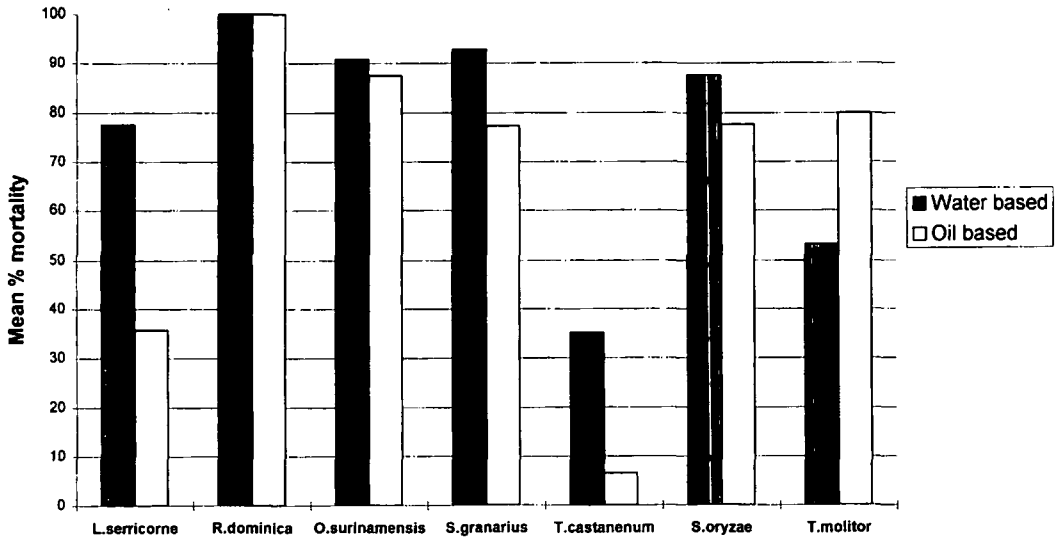

Figure 3. Warehouse trials – comparative performance of water and oil based formulations against stored product beetles. Both products applied at 4 mg/m^3 pyrethrins.

Physical data

An initial droplet size of 7 μm MMD was recorded for the FFAST formulation compared with 3 μm for the oil based product (Figure 4). In both instances initial sizes were small because the spray path was initially away from the droplet size analyser (QCM). Spray droplets therefore took longer to reach the QCM giving time for evaporation to occur, resulting in a low MMD before spray application nearer the QCM increased recorded values. The overall picture however is one of declining droplet size once spraying had been completed (20–25 minutes), with the FFAST spray retaining a larger drop size throughout the 3 hour recording period. Aerial concentration of pyrethrins measured by personal air samplers declined with time for both formulations following application (Figure 5). With the oil based formulation initial levels were close to the target dose of 4 mg/m^3 pyrethrins. Far lower initial levels were recorded with the FFAST formulation, with approximately one third of the pyrethrins applied detected 20 minutes post spray. This reduction is

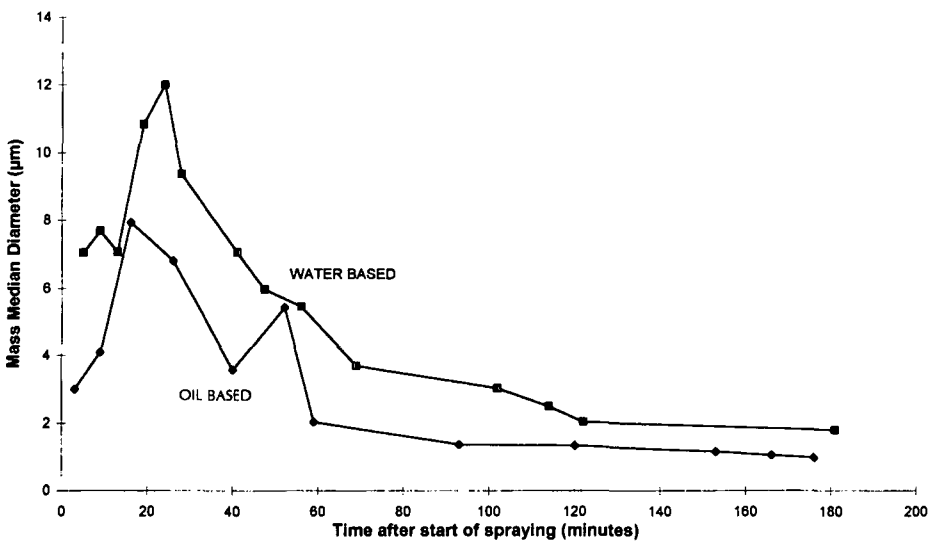

Figure 4. Warehouse trials – droplet size after ULV application of oil and water based formulations applied at 4 mg/m^3 pyrethrins.

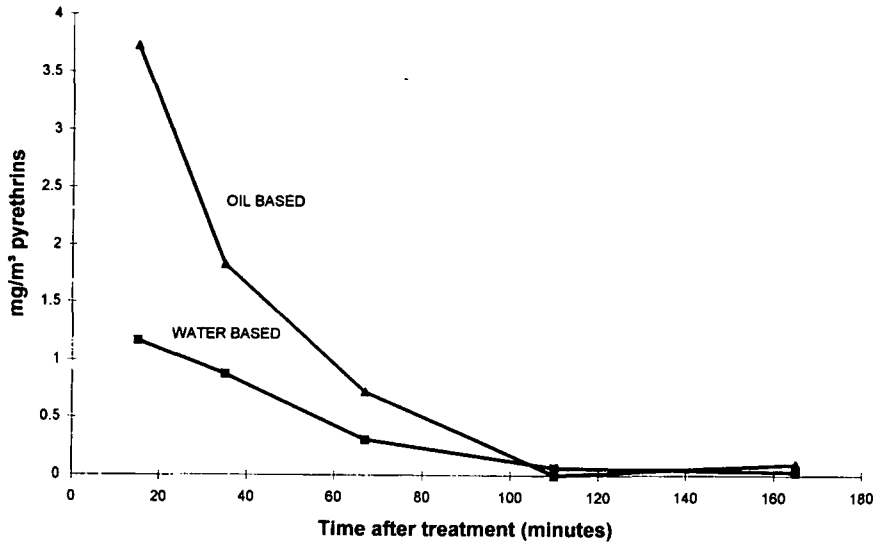

Figure 5. Warehouse trials – aerial concentration after ULV treatment at 4 mg/m^3 pyrethrins with oil and water based formulations.

a feature of the larger droplet size and therefore more rapid deposition of the FFAST presentation. The aluminium deposit sampling data (Figure 6) demonstrates this clearly, with almost double the rate of deposition occurring from the water based spray in the first 30 minutes.

Analytical data

Results of chemical analyses (Figure 7) highlight the extremely short persistence of pyrethrins, even under these relatively dim lighting conditions, with half-lives of 1.0 and 1.2 days calculated for the 1 and 4 mg/m3 treatments, respectively. The photolabile properties of pyrethrins are well documented (e.g. Chen and Casida, 1969; Bullivant and Pattenden, 1976a) and make this formulation particularly suitable for use in chemically sensitive situations such as food handling and tobacco processing premises.

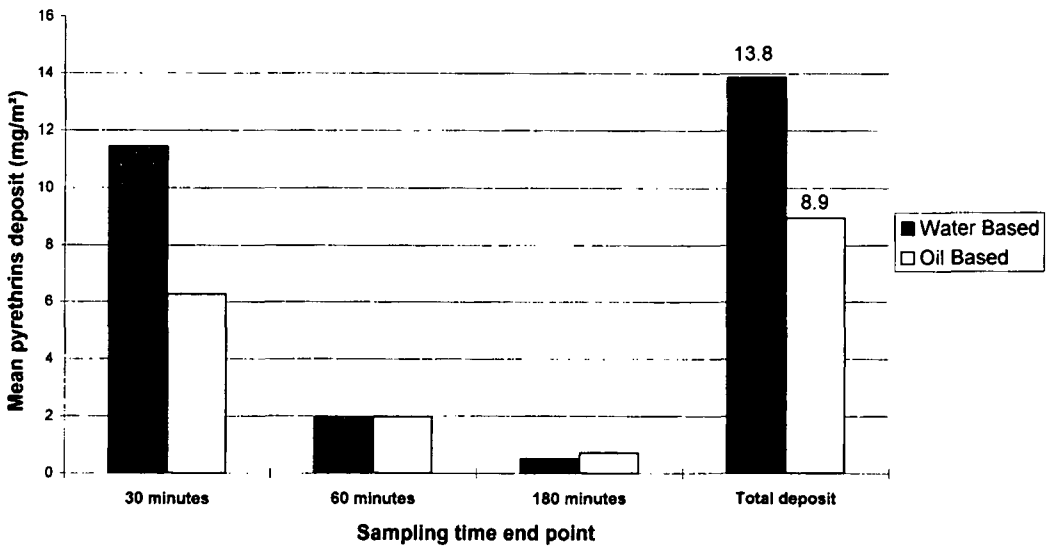

Figure 6. Warehouse trials – active ingredient deposition following ULV application of oil and water based formulations at 4 mg/m^3 pyrethrins.

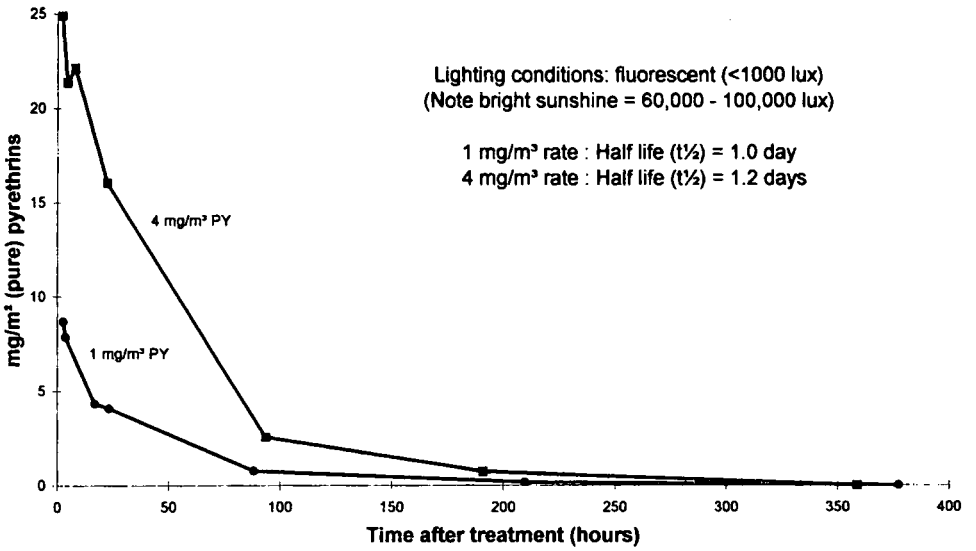

Figure 7. Warehouse trials – Degradation of pyrethrins after application of water based formulation as a ULV aerosol.

Observations

The low oil content of the FFAST formulation left no obvious residues on floors or on delicate materials such as plastics, bare metal and paper. This was in contrast to the slight spotting, particularly on plastics, noted after oil based applications.

Surface spray trials

When applied as a surface spray rapid flushout and knockdown of harboraging insects was observed. Monitoring data indicates a marked reduction in population size immediately following treatment (Figure 8). This however was relatively short lived compared to reductions typically

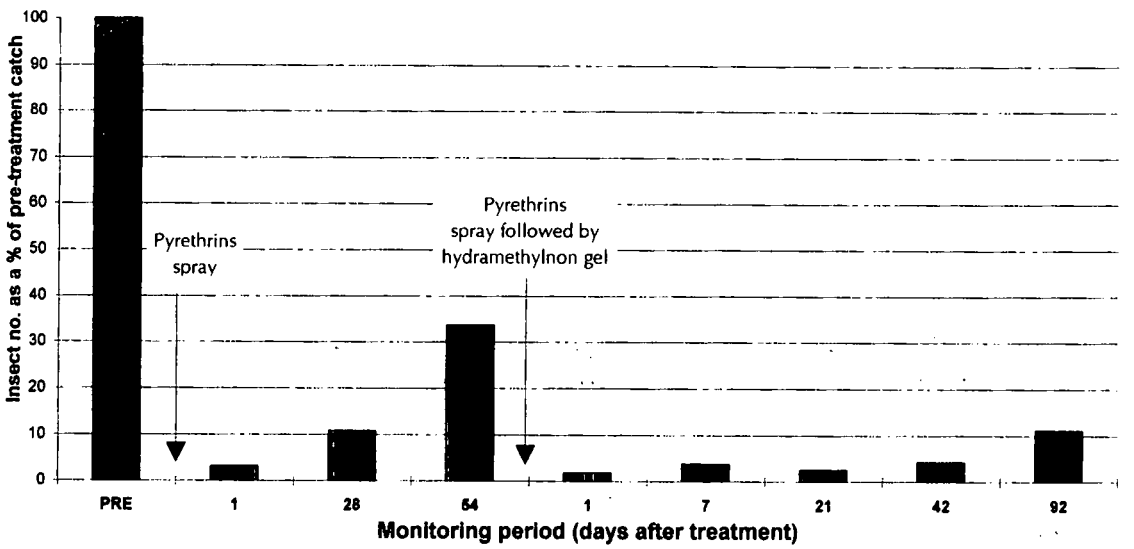

Figure 8. Field trials – water based formulation applied at 0.075% pyrethrins against a large *Blattella* infestation, followed by a combined treatment with hydramethylnon gel.

observed after residual insecticide treatments. Re-treatment 54 days later, combined with an application of hydramethylnon gel immediately after spraying gave a similar rapid population reduction, which was maintained over a much longer period.

DISCUSSION

Results of space spray trials demonstrate that under indoor conditions water based formulations can give improved biological performance against both flying and crawling insects when applied as a ULV spray when compared with conventional oil based products. This differs from outdoor situations where FFAST formulations normally provide equivalent activity (Slatter *et al.*, 1993). The better performance against flying insects under this indoor situation is due to the maintenance of a biologically more effective droplet size range compared with the oil formulation. This has resulted in more rapid deposition of the larger droplets soon after application. The shorter time droplets are airborne and vulnerable to loss through ventilation or impaction on vertical surfaces has also resulted in a greater overall deposition from the water based formulation, even though both products were applied at the same initial dose rates. This has improved performance against crawling insects.

An additional benefit of the faster settling and therefore lower aerial concentrations of this particular FFAST formulation is a reduction in re-entry and ventilation times when compared with an oil based equivalent.

When applied as a surface spray the FFAST formulation gave good knockdown and kill of directly treated cockroaches. The resulting deposit provided a short term residual effect, with population numbers increasing within a few weeks of treatment. This is due to the photolabile nature of pyrethrins and is in contrast to the sustained reductions typical of treatments with photostable residual insecticides such as deltamethrin (Lucas *et al.*, 1993). Re-treatment in combination with hydramethylnon gel, which was applied directly after surface spraying when the deposit was still wet, once again provided a rapid and this time sustained reduction in insect numbers.

Two approaches could therefore be adopted when using this product as a surface spray: either to give a rapid clear-out of insects, followed by re-treatment as necessary, or to combine with a suitable product such as a bait or an insect growth regulator to provide longer term control.

CONCLUSION

The flexibility of this FFAST formulation allows use as both a space and surface spray providing rapid knockdown and kill of directly exposed insects. The photolabile properties of pyrethrins, which provide only a short term residual effect, and the low mineral hydrocarbon content makes this formulation highly acceptable for use in sensitive locations such as food handling and storage facilities. In sensitive locations infested with cockroaches a water based pyrethrins surface spray treatment can be used in combination with relatively slow acting but longer lasting products like cockroach baits to provide a rapid knockdown and kill effect.

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