NEW USES FOR ALLETHRIN SERIES COMPOUNDS AGAINST PUBLIC HEALTH & STORED PRODUCT PESTS

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Abstract—Laboratory comparisons of pyrethroid toxicities on a range of insect pests demonstrated greater kill activity than expected for the photolabile allethrin series compounds relative to other pyrethroids. Further investigation in chamber and warehouse trials confirmed the utility of S-bioallethrin in space sprays at economic use rates for the control of public health and stored product insect pests.

INTRODUCTION

First generation pyrethroids have traditionally been used as knockdown agents often in conjunction with pyrethroid kill agents and synergists to increase the potency and spectrum of activity of indoor insecticidal sprays. The activity of individual molecules and isomers varies considerably between pest species. The levels of synergism also vary widely both with insecticide and species. A study was therefore undertaken to investigate:

(1) the potential for use of an allethrin series molecule in situations that require high activity and short residuality.

(2) whether a synergist was required to achieve good knockdown activity and mortality at economically acceptable rates.

MATERIALS AND METHODS

Insects

Adult, mixed sex cat fleas (*Ctenocephalides felis*) were obtained from the Veterinary Entomology Laboratory of the Department of Entomology, Louisiana State University.

The following susceptible strain insects were obtained from laboratories at AgrEvo Environmental Health (AEH) USA and AEH UK:

Adult, mixed sex cigarette beetles (*Lasioderma serricorne*)
Adult, mixed sex red flour beetles (*Tribolium castaneum*)
Adult, mixed sex confused flour beetles (*Tribolium confusum*)
Adult, mixed sex saw-toothed grain beetles (*Oryzaephilus surinamensis*)
Adult male German cockroaches (*Blattella germanica*)
Adult male American cockroaches (*Periplaneta americana*)
Adult male Oriental cockroaches (*Blatta orientalis*)
Adult, mixed sex warehouse moths (*Ephestia cautella*)
Adult, mixed sex houseflies (*Musca domestica*) (USA study)
Adult female houseflies (*Musca domestica*) (UK study)
Adult female southern house mosquitoes (*Culex quinquefasciatus*)

Insecticides

The following compounds were used:

S-bioallethrin (Esbiol®), Bioallethrin (Bioallethrine®), Prallethrin (ETOC™), Resmethrin, Pyrethrins, Permethrin, Tetramethrin (Neo-pynamin™), Piperonyl Butoxide.
All dilutions are expressed as % w/v (pure).

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Cat Flea Lethal Dose

Compounds without piperonyl butoxide were evaluated by exposing adult fleas to a range of insecticide deposits on filter paper. These were prepared by pipetting 100 µl acetone solutions evenly onto both sides of 3 cm diameter filter papers at a rate of 14 µl/cm^2. Treated papers were allowed to dry for 2 hours, then transferred to a 3 ml vial into which 10 adult fleas were then added and the vial capped. Control vials contained papers treated with acetone alone. Vials were kept at 24°C, 70% R.H. for 24 hours, when mortality was recorded. Four replicates were conducted.

Cat Flea knockdown

Knockdown activities of these compounds without and with piperonyl butoxide were evaluated on 5 cm diameter circles of nylon carpet. Solvent-based dilutions were sprayed at an application rate of 4 ml per 1000 cm^2 with a DeVilbiss spray nozzle at 20 p.s.i. Treated carpet was immediately placed in the bottom of a 500 ml glass cylinder of the same diameter as the carpet disc, and 10 adult fleas transferred into the cylinder. Knockdown was recorded every 30 seconds until at least 90% was achieved. Carpet treated with blank solvent was used for controls. Insects were held at 24°C and mortality was observed after 24 hours. Each treatment was replicated 4 times.

Analysis of Laboratory Data

Data were corrected for control mortality with Abbott's formula and then subjected to probit analysis. The time (in minutes) taken to knock down 50% and 90% of individuals (KT_{50} and KT_{90}), and lethal doses (LD_{50} and LD_{90}) were then determined. Where the effect of synergism was evaluated, efficacy data were compared at different concentrations, with and without piperonyl butoxide, for each insecticide.

Laboratory Chamber Space Sprays

Based on relative potencies determined from previous studies, ranges of projected use rates (mg a.i./m^3) of S-bioallethrin, prallethrin, pyrethrins and synergized pyrethrins were sprayed as solutions in Isopar M with an airbrush in a 42 m^3 room. Batches of 100 houseflies were relased into the chamber prior to test. German cockroaches were held in PTFE coated plastic dishes placed on the chamber floor while moths were held 1.5 m above the floor in netting covered cages. After a two hour exposure, insects were transferred to a holding room, with mortality assessed after 24 hours.

In a separate series of tests solvent-based formulations containing S-bioallethrin were applied with a Microgen E-2 unit at 1.05 ml formulation/m^3 (equivalent to the US standard rate of 1.0 fl.oz./1000 ft^3) in a 28.3 m^3 chamber. German cockroaches, fleas, red flour beetles and saw-tooth grain weevils were tested. A minimum of ten cockroach, flour and grain beetles were each held in four talc coated dishes. Houseflies were held in groups of 20 in four netting covered cages. Batches of 50 fleas were placed in each of four 5 gallon buckets, with the base of each lined with carpet. Insects were exposed to treatments for two hours and mortality assessed at 24 hours.

Field Testing of Space Sprays

Initial field testing was run in the USA in a 1600 m^3 building. Insect species were as tested in the laboratory (less fleas, plus cigarette beetle). As in the laboratory, four locations of insects were utilized per replicate. A two nozzle Microgen E-44 unit was used to dispense an appropriate dosage (6-15 mg a.i./m^3) of an oil based S-bioallethrin formulation. Insects were exposed for two hours with mortality assessed at 24 hours.

Larger scale field testing was conducted in the UK in a 17,500 m^3 warehouse. An S-bioallethrin concentrate was applied from a TurboCide® GOLD (Gas Operated Liquid Dispensing) two nozzle block system. Each block consists of 4 orifices, each set at 90(to each other in the horizontal plane. Insect test locations were placed at varying distances from the two nozzles, and were positioned both in- and out-of-line with the direction of formulation delivery. Dosages tested ranged from 3-12 mg a.i./m^3, with insects exposed for two hours. Following exposure insects were collected for 24 hour mortality assessments.

German, Oriental and American cockroaches, red and confused flour beetles and saw-toothed grain beetles were placed into PTFE treated plastic dishes. Cigarette beetles were placed into netting covered dishes. Houseflies, mosquitoes and warehouse moths were placed into netting covered cages.

RESULTS AND DISCUSSION

Cat flea Lethal Dose

S-bioallethrin demonstrated the greatest activity (Table 1) with an *LD50* of 12.4 μg/cm^2, levels for other actives ranging up to over 140 μg a.i./cm^2. Relative potency for the LD^{50} (1=lowest activity, relative to permethrin) ranged up to maximum of 6.8 for S-bioallethrin.

Cat flea Knockdown

Knockdown times with S-bioallethrin (Table 2) occurred in a narrow range for both KT_{50} (1.1-1.3 minutes) and KT_{90} (1.9-2.2 minutes). A lower factor of synergism was found with S-bioallethrin than permethrin, prallethrin or pyrethrins. For S-bioallethrin, the KT_{50} improved by <10 seconds with the addition of piperonyl butoxide (Table 3) and the KT_{90} decreased by <30 seconds. Permethrin and prallethrin as unsynergized actives had slower knockdown times relative to S-bioallethrin, but had better improvements in knockdown with the addition of piperonyl butoxide as a synergist (>1 minute improvements). Unsynergized S-bioallethrin had faster knockdown times than permethrin or prallethrin with a synergist. Synergized S-bioallethrin gave equivalent knockdown times to synergized pyrethrins.

Laboratory space spray tests

Experimental space spraying in a 42 m^3 chamber (Table 4) demonstrated that S-bioallethrin applied without a synergist gave acceptable control levels at low use rates. Against the German cockroach S-bioallethrin was similar in activity to prallethrin and was more active than pyrethrins (with or

Table 1. Activity of unsynergized insecticides on cat fleas.

Active ingredient	LD_{50} (μg a.i/cm^2)	Relative Potency	Slope
S-bioallethrin	12.4	6.8	8.89
Prallethrin	21.4	4.0	1.18
Bioallethrin	33.8	2.5	0.09
Resmethrin	52.8	1.6	0.12
Pyrethrins	54.4	1.6	0.13
Permethrin	84.9	1.0	0.10
Tetramethrin	>140	–	–

Table 2. Knockdown times (minutes) for unsynergized insecticides sprayed directly onto adult cat fleas on carpet.

	S-bioallethrin		Permethrin		Prallethrin		Pyrethrins	
%	KT_{50}	KT_{90}	KT_{50}	KT_{90}	KT_{50}	KT_{90}	KT_{50}	KT_{90}
0.01	1.3	2.2	3.0	5.2	2.9	5.2	4.4	7.3
0.02	1.2	2.2	3.0	5.1	3.2	5.7	3.1	5.2
0.05	1.2	2.4	1.8	4.1	3.0	5.6	3.5	5.7
0.10 1.2	2.1	1.9	4.0	1.5	2.6	1.5	2.8	2.8
0.20	1.1	1.9	1.8	3.5	1.3	2.0	1.3	2.0

Table 3. Knockdown times (minutes) for synergized (1:10 Piperonyl Butoxide) insecticides sprayed directly onto adult cat fleas on carpet.

	S-bioallethrin		Permethrin		Prallethrin		Pyrethrins	
%	KT_{50}	KT_{90}	KT_{50}	KT_{90}	KT_{50}	KT_{90}	KT_{50}	KT_{90}
0.01	1.2	2.0	1.4	4.2	1.6	2.6	1.4	2.6
0.02	1.2	2.3	1.6	4.2	1.4	2.4	1.4	2.3
0.05	1.1	1.9	1.3	2.3	1.4	2.1	0.9	1.5
0.10	0.9	1.8	1.5	2.9	1.1	2.0	0.9	1.5
0.20	0.8	1.3	1.3	2.3	1.1	2.0	0.7	1.3

Table 4. Activity of space sprays in a 42 m^3 chamber (UK, 1995).

	Mean % mortality at . . . mg a.i./m^3													
	S-bioallethrin			Prallethrin			Pyrethrins				Pyrethrins+PBO			
	2	4	8	1	2	4	4	8	16	32	1	2	4	8
B. germanica	58	98	100	27	36	96	27	40	70	84	13	27	68	84
M.domestica	46	88	98	38	100	–	87	99	–	–	100	100	–	–
E. cautella	89	100	–	67	78	95	100	100	–	–	88	98	–	–

– not tested.

without piperonyl butoxide). These results also highlight the benefit of using piperonyl butoxide as a pyrethrins synergist, especially for flying insect control. Results warranted proceeding on a larger scale with prototype S-bioallethrin formulations applied with commercial application equipment.

Chamber Test with Formulated Space Sprays

In laboratory testing, S-bioallethrin in an oil-based formulation delivered with commercial aerosol generating equipment gave acceptable control after 2 hour exposures of German cockroach, cat flea, housefly and stored product beetles (Table 5).

Field evaluation of S-bioallethrin in 1600 m^3 building, USA

Excellent control of cockroaches and stored product pests was achieved under field conditions with an experimental S-bioallethrin formulation applied with commercial application equipment at between 6-9 mg a.i./m3 (Table 6).

Field evaluation of an S-bioallethrin space spray in a 17,500 m^3 warehouse

Effective rates for two hour exposure times ranged from 3 to 12 mg a.i./m^3 in an industrial situation for a broad range of key pest species as shown in Table 7.

Table 5. Activity of an S-bioallethrin space spray in a 28.3 m^3 chamber (USA, 1995).

	Mean % mortality at ....mg a.i./m^3			
	3	6	9	15
T. castaneum	–	94	–	–
O. surinamensis	–	100	–	–
B. germanica	25	100	100	–
M. domestica	89	98	100	–
C. felis	–	65	–	94

– not tested.

Table 6. Control of insect pests in a 1600 m^3 building with an oil-based S-bioallethrin formulation applied through a mechanical aerosol generator (USA, 1995).

	Mean % mortality at ....mg a.i./m^3			
	6	9	12	15
T. castaneum	82	–	100	–
T. confusum	–	100	–	100
O. surinamensis	48	100	00	–
L. serricorne	90	100	100	–
B. germanica	90	100	–	–

Table 7. Control of key insect pests with S-bioallethrin dispensed with a Gas Operated Liquid Dispensing System in a 17,500 m^3 building (UK, 1995).

	Mean % mortality at ....mg a.i./m^3			
	3	6	9	12
T. castaneum	51	63	63	80
T. confusum	33	54	80	87
O. surinamensis	34	49	63	86
L. serricorne	88	94	100	100
P. americana	60	95	95	98
B. orientalis	25	100	100	100
B. germanica	100	100	100	100
M. domestica	86	84	100	–
E. cautella	100	100	–	–
C. quinquefasciatus	100	100	–	–

– not tested.

CONCLUSIONS

S-bioallethrin indoor space spray formulations were demonstrated to be capable of providing control of key public and stored product insect pests at economic use rates. This was accomplished with S-bioallethrin alone and without synergists or the use of traditional pyrethroid kill agents.