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PERSISTENCE OF THREE SYNTHETIC PYRETHROIDS IN JAMAICAN SOILS

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ABSTRACT

Persistence of three pyrethroids (decis, permethrin and phenothrin) in three types of Jamaican soils - Chudleigh clay loam (CCL) Sydenham clay loam (SCL) and Marvally sandy loam (MSL) at three moisture levels (5, 10 and 15%) was assayed with adult Tribolium confusum.

The LT_{50} values of $LC_{50 \times 4}$ doses of the insecticide in CCL, SCL and MSL and at 15% moisture level were respectively, 2.56, 2.25, and 3.10 for phenothrin, 3.86, 3.11 and 4.09 for permethrin and 3.18, 3.98 and 3.83 for decis. The LT_{50} values for $LC_{50 \times 2}$ doses were generally lower than that of the higher dose, being 2.49, 1.60 and 2.62 for phenothrin, 2.89, 2.56, 3.50 for permethrin and 2.06, 3.77 and 3.26 for decis, respectively.

INTRODUCTION

Many soil dwelling insects, defined by Lilly (1956) as those which spend at least part of their life cycle in soil, are regarded as serious pests of agricultural crops and forest trees around the world (Harris, 1972). In Jamaica, there are a number of soil insects of economic importance. These include the citrus root weevils (Exophthalmus vittatus Linne, E. similis Drury, E. viridipupillatus cockerell, E. farr Vaurie, E. impressus Fabricus, and Pachnaeus citri Marshall) commonly known as fiddler beetles, the cicada on coffee, scarabid beetle larvae on vegetables and ornamentals and armyworms and other noctuid larvae (Mansingh and Reid, unpub).

Before the 1940's chemical control of soil insects was difficult since the arsenicals, the only insecticides then available for the purpose, tended to be more toxic to vegetation than to the insects. Botanical insecticides were also used but they proved to be very unsuitable and ineffective (Lilly, 1956). With the advent of modern organic insecticides, chlorinated hydrocarbons (OCs) were used extensively against soil insects. However, because of long persistence of the OCs, the associated adverse environmental effects, and the development of resistance to the chemicals by many insect species, these chemicals have been gradually replaced by the organophosphorus compounds (OPs) and the carbamates. The factors influencing the bioefficacy and persistence of these insecticides in soils have been reviewed extensively by Lilly (1956) Edwards (1966 ; 1969 1971 ; 1978), Harris (1972), Anderson (1987) and Gayle (1988). Recently, attention has been focussed on pyrethroids as possible candidates for soil insecticides (Harris and Turnbull, 1978; Sakata et al 1986).

In Jamaica dieldrin has been used for about forty years against the fiddler beetles but is now ineffective in controlling the pest (Biggs and Mansingh unpub.). The present laboratory studies were therefore undertaken for assessing the bioeffectiveness and persistence of three pyrethroid insecticides in three types of Jamaica soils in which citrus and vegetables are commonly grown.

MATERIALS AND METHODS

The experimental soils were classified according to the Soil and Land Use Surveys of Jamaica (1954-1957). Chudleigh clay loam (CCL) was obtained from the parish of Manchester, Sydenham clay loam (SCL) from St. Catherine and Marvely sandy loam from St. Andrew. Samples of each soil type were collected from at least five different locations in fallow agricultural land, to a depth of 30cm, pooled, air dried, ground coarsely and passed through a 2mm sieve to provide uniform particles.

About 1kg samples of each soil type were provided to the Soil Chemistry and Analytical Laboratory, Ministry of Agriculture, Jamaica for physical and chemical analyses. For bioassay purposes coarsely ground soil, with about 2% moisture level was stored in the laboratory. Before treatment of soils with insecticides the moisture content was determined by drying three 50g replicates to a constant weight.

Soil samples of 50g each in glass dishes were mixed with insecticidal emulsions in varying amounts of water to provide the desired concentrations of insecticides and moisture levels (5, 10 and 15%). Five concentrations of each insecticide designed to give 15-85% mortality (as determined by preliminary tests) were used to determine 24 hour LC_{50} values at different moisture levels. Each concentration had three replicates. For persistence trials 50g soil samples with three replicates were treated with $LC_{50 \times 2}$ and $LC_{50 \times 4}$ doses of the insecticides at the appropriate moisture levels. The petri dishes were kept covered with glass tops (except when the test insects were released for bioassay) to retain moisture. The moisture levels were brought up at weekly intervals by adding the desired amount of water, as determined by the water loss standard curve prepared simultaneously with untreated soil samples maintained under experimental conditions.

Adult Tribolium confusum Duval were collected from the laboratory culture, starved for 4 to 6 hours and released (20 per replicate) on the treated and control soils. The dishes were covered with fine nylon mesh and 24 hours later, mortality was counted. The data was subjected to prohibit analysis according to Busvine (1972). LT_{50} values were calculated for each insecticide.

RESULTS AND DISCUSSION

The physical and chemical properties of the three test soils (Table 1) shows that the Chudleigh soil (CCL) was characterized by high organic matter (OM) and clay contents (6.3 and 32.1% respectively), while the Sydenham soil (SCL) had highest clay (36.3% and relatively low OM (3.29%), Marvely soil (MSL) had the least clay (14.48) and OM (2.7%) contents.

The LC_{50} value of phenothrin in CCL was lowest and the persistence highest at 10% moisture level than at 5% or 15% (Table 2). The persistence of the $LC_{50 \times 2}$ dose was also significantly less at 10% moisture level than the higher dose. Also, permethrin, though showing consistently longer persistence of the higher doses than the lower ones at all moisture levels, was most effective and persistent at 10% than at the lower or higher moisture levels. Decis was most effective at 15% moisture but was almost equally persistent at 5 and 10% moisture levels.

In SCL, the LC_{50} values of phenothrin and permethrin are not significantly affected by moisture levels, but the persistence is generally longer at 10% moisture level than at 5 or 15% and the higher doses were significantly more persistent than the lower ones. Decis is most effective ($LC_{50} = 0.021\%$) and most persistent ($LT_{50} = 3.77$ and 3.98 weeks) at 15% than at 5 and 10% moisture contents. However, the persistence of higher and lower doses were not significantly different.

At 15% moisture level in MSL phenothrin was most effective ($LC_{50} = 1.95 \times 10^{-3}\%$) but least persistent ($LT_{50} = 2.62$ and 3.1 weeks) than at 5 or 10% moisture levels (Table 4). Permethrin also had lower LC_{50} values at 10 & 15% moisture contents but persisted longest ($LT_{50} = 7.5$ and 8.26 weeks) at 5% moisture level. Decis, too, was most effective and least persistent at 15 and 10% than at 5% moisture content.

The present results suggest that decis and permethrin were fairly persistent (maximum LT_{50} values 9.98 and 8.26 weeks respectively) as compared to phenothrin (maximum LT_{50} value of 5.69). Other authors have noted that bioactivity (inflicting about 50% mortality) of the pyrethroids in soils usually only lasts for a couple of weeks though the residues may be detected for 8 to 16 weeks (Chapman et al 1981; Cheng, 1984). In temperate sand, decamethrin and fenvalerate were found to be the most persistent pyrethroids with $t_{1/2}$ values of about 30 days (Hill, 1981; Schimmel, et al, 1983). Permethrin was almost as persistent as WL 43775, followed by fenpropanate and cypermethrin (Kaufman et al, 1981; Williams and Brown, 1979; Harris et al 1981).

Contrary to the general trend of the OCs and OPs which persist longer in mineral soils than in sandy soils (Harris, 1972; Anderson, 1987) the pyrethroids were more persistent in sandy loam (MSL) with 2.7% O.M and about about 14.5% clay than in clay loam (CCL and SCL) with 3.3 to 6.3% O.M and about 32 to 36% clay. Obviously, the organic matter content determines the rate of degradation of the chemicals more than their ability to adsorb on the soil particles and reduce volatilization. Sakata et al (1986) had reported faster degradation of cypermethrin in sandy soil with only 7.2% clay but high (6.2%) OM content, than in clay soil with 21% clay and only 0.4% OM contents. Fairly rapid microbial degradation of pyrethroids has been demonstrated by Chapman et al (1981).

The observed longer persistence of the pyrethroids in MSL than in SCL and CCL probably demonstrate the greater availability of the insecticide for bioactivity in sandy loam than in clay loam, rather than the amounts of residues per se. In clay loam, the chemicals are adsorbed to

soil particles at lower moisture contents and not available for exerting toxic action on the insect; at high moisture level, the insecticidal molecules are released but degrade quickly by chemical and microbial hydrolysis. These processes would show less bioeffectiveness in clay loams at low moisture levels, and cause rapid disappearance of the pyrethroids at high moisture levels.

The longer persistence of the test pyrethroids at 5 and 10% than at 15% moisture contents suggests fairly rapid hydrolysis of the chemicals at high moisture levels, regardless of soil type. Sakata et al (1986) had demonstrated that hydrolysis is one of the major degradation processess for pyrethroids which takes place both in acidic and alkaline media.

Higher doses ($LC_{50 \times 4}$) persisted generally longer than the lower doses ($LC_{50 \times 2}$) a phenomenon which has been demonstrated with OCs and OPs by Edwards (1964) and Satcher et al (1972).

Pyrethroids, particularly decis and permethrin may be effective soil insecticides in the tropics whose soils are generally poor in organic matter content. If the timing of soil application is properly determined, pests like the armyworm can be sucessfully controlled.

Table 1: Physical and chemical properties of three types of Jamaican Soils.

Character	SCL	Soil Types MSL	CCL
Sand %	46.11	64.52	47.07
Silt %	17.59	21.00	20.81
Clay %	36.30	14.48	32.12
pH	7.30	7.30	6.50
Organic matter %	3.29	2.70	6.32
Ca Meq/100g	24.50	14.40	10.88
Mg "	10.51	1.56	1.29
K "	1.34	0.21	0.15
Na "	0.87	0.21	0.00
AL "	0.00	0.05	0.11
C.E.C.	35.20	15.20	12.80
Fe ppm	565.00	75.00	17.20
K ₂ O ppm	74.00	166.00	95.00
P ₂ O ₅ "	232.00	172.00	125.00
Na%	0.17	0.10	0.32

1. SCL Sydenham clay loam; MSL, Marvelly sandy loam; CCL, Chudleigh Clay Loam;
2. meg/100g; 1 mol per ion exchange number per 100g soil.
3. C.E.C., cation exchange capacity.

Table 2: Persistence of the three pyrethroids in Chudleigh Clay loam at different moisture levels as determined by bioassay for LT_{50} on adult T. confusum

Insecticide	Moisture %	Concentration %	LT_{50} weeks	Fiducial limits	Regression Equation
Phenothrin	5	1.00	2.89	2.54 - 3.26	$y = 6.441 - 3.127x$
		2.00	2.98	2.24 - 3.92	$y = 6.924 - 4.051x$
		0.76	3.54	2.36 - 4.68	$y = 5.520 - 0.947x$
	10	1.52	5.51	2.24 - 6.10	$y = 6.497 - 2.022x$
		0.69	2.49	2.21 - 4.26	$y = 7.036 - 5.143x$
		1.38	2.56	2.01 - 3.50	$y = 7.079 - 5.093x$
Permethrin	5	0.34	2.92	2.91 - 2.92	$y = 6.839 - 3.956x$
		0.68	3.91	3.90 - 3.94	$y = 9.536 - 7.668x$
		0.31	3.69	1.37 - 4.76	$y = 6.359 - 2.398x$
	10	0.63	5.78	4.24 - 6.99	$y = 7.299 - 3.019x$
		0.31	2.89	1.92 - 4.09	$y = 5.945 - 2.054x$
		0.62	3.86	3.38 - 4.28	$y = 6.952 - 3.332x$
Decis	5	0.04	2.08	1.85 - 2.39	$y = 5.947 - 2.976x$
		0.09	3.07	2.87 - 3.39	$y = 8.832 - 6.753x$
		0.04	2.23	1.96 - 2.60	$y = 6.090 - 3.135x$
	10	0.08	2.73	2.45 - 3.10	$y = 6.645 - 3.769x$
		0.02	2.06	1.55 - 3.21	$y = 5.861 - 2.751x$
		0.04	3.18	2.98 - 3.41	$y = 7.888 - 5.736x$

1. The lower and higher doses represented the $LC_{50 \times 2}$ and $LC_{50 \times 4}$ values, respectively at a particular moisture level as determined experimentally.

Table 3: Persistence of three pyrethroids in Sydenham clay loam and different moisture levels as determined by bioassay for LT₅₀ on adult T. confusum.

Insecticide	Moisture %	Concentration %	LT ₅₀ weeks	Fiducial Limits	Regression Equation
Phenothrin	5	0.584	1.13	0.91 - 2.19	y = 5.139 - 2.599x
		1.168	2.55	2.40 - 2.78	y = 7.490 - 6.127x
		0.582	2.90	2.75 - 4.62	y = 7.689 - 5.817x
	10	1.164	3.42	3.11 - 3.74	y = 6.788 - 3.348x
		0.562	1.60	1.46 - 1.80	y = 5.697 - 3.401x
		1.124	2.25	2.09 - 2.45	y = 6.418 - 4.015x
Permethrin	5	0.448	1.95	1.23 - 3.25	y = 6.414 - 4.900x
		0.896	2.48	1.48 - 3.92	y = 6.712 - 4.349x
		0.420	2.67	2.01 - 3.52	y = 7.786 - 6.519x
	10	0.840	4.30	4.06 - 4.50	y = 9.396 - 6.950x
		0.390	2.56	2.42 - 2.71	y = 7.446 - 5.998x
		0.780	3.11	2.99 - 3.25	y = 9.416 - 8.962x
Decis	5	0.076	3.08	2.66 - 3.88	y = 9.189 - 8.589x
		0.152	3.53	3.35 - 3.74	y = 9.448 - 8.112x
		0.052	3.18	3.03 - 3.35	y = 8.283 - 6.533x
	10	0.104	3.42	2.71 - 4.28	y = 8.284 - 6.154x
		0.042	3.77	3.62 - 3.92	y = 9.970 - 8.023x
		0.084	3.98	3.81 - 4.14	y = 10.017 - 8.336x

1. The lower and higher doses represented the LC_{50x2} and LC_{50x4} values, respectively at a particular moisture level as determined experimentally.

Table 4: Persistence of three pyrethroids in Marvelly sandy loam at different moisture levels as determined by bioassay for LT₅₀ on adult T. confusum.

Insecticide	Moisture %	Concentration %	L ¹ LT ₅₀ weeks	Fiducial Limits	Regression Equation
Phenothrin	5	476.0 x 10 ⁻³	3.95	3.52 - 4.41	y = 6.524 - 2.552x
		952.0 x 10 ⁻³	5.47	3.35 - 6.99	y = 6.620 - 2.196x
	10	456.0 x 10 ⁻³	4.38	3.84 - 4.90	y = 6.211 - 1.890x
		912.0 x 10 ⁻³	5.69	5.08 - 6.24	y = 7.043 - 2.706x
	15	390.0 x 10 ⁻³	2.62	1.75 - 3.45	y = 6.316 - 3.139x
		780.0 x 10 ⁻³	3.10	2.91 - 3.31	y = 7.099 - 4.277x
Permethrin	5	310.0 x 10 ⁻³	7.50	6.42 - 8.37	y = 7.651 - 3.030x
		620.0 x 10 ⁻³	8.26	6.49 - 9.56	y = 7.699 - 2.944x
	10	226.0 x 10 ⁻³	6.05	5.47 - 6.58	y = 7.589 - 3.309x
		452.0 x 10 ⁻³	5.68	5.22 - 6.08	y = 7.828 - 3.751x
	15	220.0 x 10 ⁻³	3.50	3.35 - 3.66	y = 8.766 - 6.926x
		440.0 x 10 ⁻³	4.09	3.56 - 5.29	y = 9.956 - 8.102x
Decis	5	0.84 x 10 ⁻³	7.66	6.18 - 8.91	y = 6.736 - 1.965x
		1.68 x 10 ⁻³	9.98	7.13 - 12.01	y = 7.685 - 2.687x
	10	0.50 x 10 ⁻³	6.10	5.21 - 6.88	y = 6.652 - 2.104x
		1.00 x 10 ⁻³	5.68	5.22 - 6.08	y = 7.828 - 3.751x
	15	0.22 x 10 ⁻³	3.26	3.10 - 3.46	y = 7.551 - 4.958x
		0.44 x 10 ⁻³	3.83	3.41 - 4.44	y = 8.346 - 5.732x

1. The lower and higher doses represented the LC_{50x2} and LC_{50x4} values, respectively at a particular moisture level as determined experimentally.

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