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Persistence and Effect of Management Practices on Organochlorine Residues in Soils of Sub-Tropical New South Wales

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The presence of organochlorine (OC) insecticide residues in soils of the North Coast Region of New South Wales has previously been reported (McDougall et al 1987; Wan et al 1989). Significant levels of heptachlor epoxide and dieldrin were found following the use of dieldrin (1955-1962) and then heptachlor (1962-1984) to control African black beetle, Heteronychus arator, in maize (Zea mays). Heptachlor has also been used to control white fringed weevil larvae, Graphognathus leucoloma, in lucerne (Medicago sativa). Dieldrin has had extensive use in this region controlling soil pests in sugar cane. As a result there is a considerable area of land used for grazing and pasture crops which is contaminated with either dieldrin, heptachlor or chlordane, a contaminant of heptachlor. This land is used by farmers for grazing and growing forage crops and consequently residues are found in meat and milk produced in the region. The levels of OC residues need to be reduced to allow continued agricultural use of the land.

Little is known about the persistence of these chemicals in soil in the sub-tropical climate of New South Wales, although much has been reported for temperate regions (eg. Harris and Sans 1976; Voerman and Besemer 1975; Weise and Basson 1968). The persistence of insecticides in some sub-tropical soils elsewhere has been reported (Talekar et al 1977; Talekar et al 1983). Attempts to affect the degradation rate of these OC residues in soil by the presence of a cover crop (Lichtenstein et al 1962; Lichtenstein et al 1971), by cultivation of the soil (Lichtenstein et al 1961) and by the alteration of the soil microbial processes (Verstraete et al 1974) have been reported and reviewed (El Beit et al 1981).

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The effect of different management practices on the dissapation of OC residues in sub-tropical acid soils of NSW has not been studied. We report here results of a study to determine the persistence and effects of various management practices on OC residues in NSW soils.

MATERIALS AND METHODS

Three paddocks, two on dairy farms near Kempsey and one on a sugar cane farm near Ballina were selected. Site 1 was a Eutric fluvisol (uniform medium textured alluvial) soil, site 2 a Chromic luvisol (red podsolic) soil and site 3 a Eutric planisol (duplex grey) soil with an acid reaction trend (soil classification by FAO_UNESCO, 1974). The treatments selected are shown in table 1. The green manure crop used was dolichos lablab while a mixture of setaria sphacelata (Narok), lotus pendunculatus (Maku) and trifolium repens (Haifa) was used as a sink crop. Deep ploughing was an inversion of the soil to a depth of 500mm using a mouldboard plough.

Table 1: Management practices selected as treatments

Treatment Number	Sites*	Cultivation Frequency	Other treatments	Abbreviation
1	1,2,3	nil	Nil	Control
2	3	nil	Green manure	Manure
3	1,2,3	monthly	Nil	Mo
4	1,2,3	monthly	Hydrated lime(5T/ha)	Mo + Lime
5	1,2	monthly	Nitram(NH_4NO_3)(100kg/ha)	Mo+ N
6	3	monthly	Lime + nitram	Mo + N + L
7	3	monthly	Sept - March only	Mo-summer
8	1,2	quarterly	Nil	3 Mo
9	1,2	quarterly	Hydrated lime	3 Mo + L
10	1,2	quarterly	Nitram	3 Mo + N
11	1,2,3	annually	Nil	12 Mo
12	1,2	annually	Hydrated lime	12 Mo + L
13	1,2	nil	Deep ploughing	Deep pl.
14	3	nil	Sink crop: to be harvested periodically	Sink

Note*: Sites 1,2-Kempsey district; Site 3 - Ballina district

Randomised block treatments were carried out in triplicate, individual plots measuring 40m x 4.5m. Twenty 31mm x 150mm soil cores were taken randomly from each plot and composited. Following sieving, a 1000g sub-sample was stored at -20°C until analysis.

Individual paddocks from five farms near Kempsey were sampled to determine the 'normal' persistence of the OC residues in soil. All soils contained aged cyclodiene residues. Fifty cores (20mm x 150mm) were taken across one diagonal from each paddock, composited, sieved and a 1000g sub-sample stored at -20°C until analysis. Normal summer crop production of maize, including cultivation and preparation, was carried out each year. Pastures were grown each winter.

To extract insecticide residues from the soils, a single 100g sub-sample was shaken with 200ml acetone in a 500ml bottle for 1 1/2 hours, a method adapted from Harris and Sans (1971). After settling, a 5ml aliquot was diluted to 25mls with hexane and dried by the addition of anhydrous sodium sulphate. No cleanup was necessary. Samples were analysed using a Dani 8400 GC equipped with a ^{63}Ni electron capture detector and a 12m x 0.53mm RSL 300 megabore column (Alltech Assoc.). The injector block was lined with a glass liner and operated in splitless mode. Operating conditions were: column 200°C, injector 230°C, detector 275°C, carrier flow 5ml/min, make up gas 40ml/min.

Soil was examined for heptachlor (H), heptachlor epoxide (HE), gamma-chlordane (G) and dieldrin (D). Results are expressed in mg/kg dry soil with the limit of reporting set at 0.01 mg/kg. Quantitation was by peak height. Soil moistures were determined by microwave using the method of Thomas et al (1980). If soil moisture was less than 10% then 90g soil and 10g water was used for analysis.

Soil pH was determined in water. Soil constituents were determined according to Abbott et al (1989). Daily maximum and minimum temperatures were recorded at each site as was daily rainfall.

RESULTS AND DISCUSSION

Soil details for each site and paddock examined are shown in table 2 and the climatic details for the Kempsey and Ballina areas in Figure 1.

Table 2: Physical properties of soils used

Soil	Constituents (%) Clay	Silt	Sand	OM	pH	P-sorption Index
Site 1	22.3	33.8	46.5	2.76	4.9	4.2
Site 2	28.2	28.3	45.4	4.73	5.2	5.2
Site 3	32.0	19.8	47.2	2.76	4.7	
Paddock 1	25.7	27.4	48.5	4.08	5.7	4.6
Paddock 2	36.9	36.7	24.2	8.65	5.0	6.2
Paddock 3	30.4	42.6	28.7	3.43	4.7	4.3
Paddock 4	17.5	23.6	60.1	1.98	4.7	3.5
Paddock 5	28.4	32.0	39.0	4.86	4.9	5.7
Paddock 6	20.5	30.4	51.0	2.78	5.4	4.4

The decline of the cyclodiene residues in the paddock soils was followed for 140 weeks and results are shown in table 3. Variation in the percent remaining is considerable and does not seem to be related to any particular constituent. The results show that, on average, dieldrin is more persistent than the others and heptachlor is the least

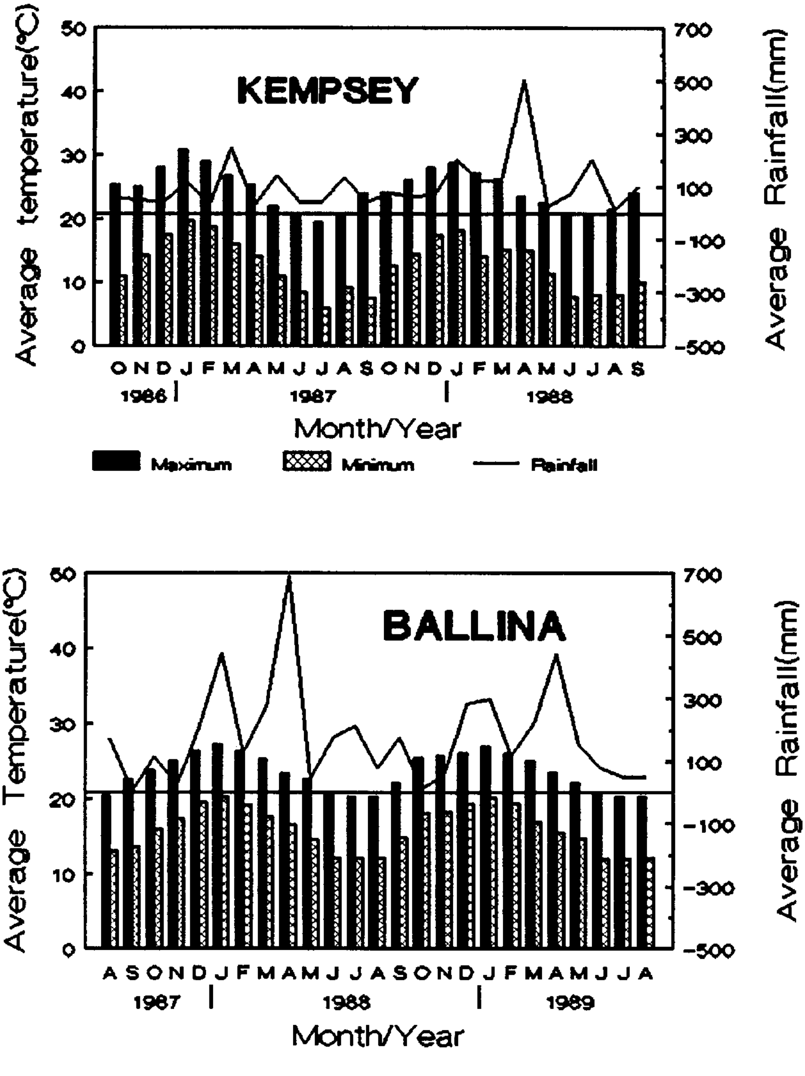

Figure 1: Climatic data from trial sites

persistent and this is in agreement with other published data with heptachlor epoxide and gamma-chlordane in between. The formula $y = ae^{-bx}$ was applied to the paddock data and also to the management site data to determine the rate of dissipation (b) and calculate the half-life as ln 2/b. Calculated half lives are shown in table 4.

The average calculated half-lives are, in general, shorter than the range of figures published by Menzie (1972). This is probably due to the sub-tropical environment, including high rainfall and high summer temperatures. The acidic soil pH would tend to increase the persistence of all the cyclodienes studied, as soil microflora are inhibited at the soil pHs encountered. The addition of lime to some blocks in the

Table 3: Dissipation of cyclodiene residues in NSW paddock soils over 140 weeks

	Initial Residue (mg/kg)				Residue at 140 weeks (% remaining)			
Soil	H	HE	G	D	H	HE	G	D
Paddock 1	0.03	0.13	0.05	-	<0.01(17)	0.04(28)	0.01(20)	-
Paddock 2	0.06	0.18	0.08	-	<0.01(22)	0.13(71)	0.06(74)	-
Paddock 3	0.04	0.15	0.10	-	<0.01(16)	0.11(75)	0.07(74)	-
Paddock 4	0.04	0.21	0.10	0.07	<0.01(23)	0.10(46)	0.07(69)	0.04(61)
Paddock 5	0.02	0.16	0.08	0.04	<0.01(20)	0.08(51)	0.03(41)	0.04(61)
Paddock 6	0.01	0.04	0.03	0.11	<0.01(35)	0.02(56)	0.01(44)	0.07(63)
Average	**0.04**	**0.15**	**0.07**	**0.08**	**<0.01(20)**	**0.08(55)**	**0.04(54)**	**0.05(62)**

Table 4: Average half-life(weeks) of cyclodiene insecticides in NSW sub-tropical soils

Soil	H	HE	G	D
Site 1	52±4.5[1]	98±5.3	95±10.2	
Site 2	90±7.1	116±9.5	73±4.6	
Site 3				362±30
Paddock 1	55	76	60	
Paddock 2	64	263	320	
Paddock 3	55	324	320	
Paddock 4	65	122	261	195
Paddock 5	67	141	110	199
Paddock 6	90	153	119	207
Average ±SE	**67±5.3**	**162±31**	**170±39**	**241±41**

Note: [1] SE listed only for sites following averaging of plots

Table 5: pH levels in soils at management practice sites

	Soil Treatment			
	No Lime		Lime Added	
Site	Initial pH	Final pH	Initial pH	Final pH
1	4.9	4.8	7.5	6.5
2	5.2	5.1	6.8	6.2
3	4.7	4.8	5.6	5.1

management practice sites altered the pH of the soil (Table 5), but to varying degrees, in an attempt to improve the microflora activity. Site 3 gave only slight change in pH and this would certainly minimise any effect of the lime.

The effect of the different management practices on the dissipation of the OCs is shown in table 6. There was no effect of the management practices undertaken at each site on the rate of dissipation of the cyclodiene residues. After 96 weeks about half of the H, HE and G had dissipated in all plots while only a slight decrease in D occurred at site 3. Other results for dieldrin indicate that the rate of dissipation at this site is much slower than at others (cf paddocks 4-6, Table 4). It could be that the cropping regime for this soil is more severe leaving the soil depleted in microflora and microfauna.

Table 6: Effect of management practices on the dissipation of cyclodiene residues in soil over 96 weeks

Site/Treatment	Initial Residue (mg/kg)				Residue remaining(%initial)			
	H	HE	G	D	H	HE	G	D
1/1-Control	0.04	0.17	0.16		0.01(32)	0.10(57)	0.05(29)	
3-Mo	0.04	0.17	0.14		0.01(22)	0.07(42)	0.08(55)	
4-Mo + L	0.04	0.17	0.14		0.01(34)	0.09(50)	0.08(54)	
5-Mo + N	0.03	0.16	0.14		0.01(44)	0.08(49)	0.09(65)	
8-3 Mo	0.05	0.17	0.15		0.01(20)	0.08(48)	0.08(53)	
9-3 Mo + L	0.04	0.16	0.13		0.01(22)	0.08(49)	0.07(51)	
10-3 Mo + N	0.05	0.19	0.16		0.01(22)	0.09(49)	0.08(48)	
11-12 Mo	0.04	0.18	0.15		0.01(26)	0.11(59)	0.06(41)	
12-12 Mo + L	0.04	0.17	0.15		0.01(22)	0.09(52)	0.06(37)	
Site 1 Average	**0.04**	**0.17**	**0.15**		**0.01(27)**	**0.09(50)**	**0.08(51)**	
2/1-Control	0.02	0.38	0.19		<0.01(41)	0.24(62)	0.04(23)	
3-Mo	0.02	0.37	0.19		<0.01(43)	0.18(48)	0.07(39)	
4-Mo + L	0.01	0.39	0.19		<0.01(48)	0.18(46)	0.07(35)	
5-Mo + N	0.02	0.36	0.18		0.01(60)	0.18(51)	0.08(43)	
8-3 Mo	0.02	0.36	0.17		<0.01(41)	0.19(52)	0.07(42)	
9-3 Mo + L	0.02	0.37	0.19		<0.01(42)	0.20(55)	0.07(39)	
10-3 Mo + N	0.02	0.36	0.18		<0.01(47)	0.22(60)	0.08(46)	
11-12 Mo	0.02	0.40	0.20		<0.01(38)	0.22(54)	0.07(36)	
Site 2 Average	**0.02**	**0.37**	**0.19**		**<0.01(46)**	**0.20(52)**	**0.08(40)**	
3/1-Control				0.19				0.16(82)
2-Manure				0.18				0.14(80)
3-Mo				0.17				0.15(86)
4-Mo + L				0.20				0.15(74)
6-Mo + N + L				0.17				0.15(85)
7-Mo-summer				0.17				0.15(85)
12-12 Mo				0.17				0.15(87)
14-Sink				0.17				0.14(80)
Site 3 Average				**0.18**				**0.15(82)**

The frequency of cultivation had no effect. The three soils did not have the structure to withstand more frequent cultivating as used by Lichtenstein (1961) where he measured an effect with daily discing. Ours soils were acid, our residue was an 'old' residue and our frequency much less and some or all of these factors could have influenced the results. The pH of the soil at sites 1 and 2 was altered substantially (table 5) but there was no beneficial effect on the persistence of the heptachlor and chlordane. Nitrate was added as an external electron acceptor in anaerobic metabolic respiration (Sokatch J R 1969) to try and enhance bacterial action on the cyclodienes. Even in the presence of lime to alter the pH no effect was measured.

The lack of response to lime or lime and nitrate suggests either an absence in the soil of organisms that will break down cyclodiene residues or that if there were such organisms present they were insensitive to pH change or were pushed out by those organisms that did respond to lime.

The use of sink crops, the addition of manure or the use of a cover crop as in the controls had no apparent effect on the dissipation of the cyclodiene residues.

Deep ploughing reduced all soil residues by 40 and 50% respectively for sites 1 and 2. Dissipation of the residues continued at normal rates thereafter. Deep ploughing could be utilised as a means of reducing soil bound residues where soil depth allowed.

We conclude that in all attempts in our work reported here we were unable to enhance the rate of decline of any of the cyclodienes. They are all persistent in our sub-tropical environment and this is most likely an effect of the acid soils in our region. Only deep ploughing reduced residues beyond the normal dissipation rate.

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