Absorption of Organochlorine Insecticide Residues from Agricultural Soils by Root Crops

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Root crops were planted in sandy loam, clay, and muck soils known to contain high residues of six to seven organochlorine insecticides or their metabolites. Cyclodiene insecticide residues were detected in the crops, but only trace amounts of DDT and DDE were present. Carrots absorbed the most residue > radishes > turnips > onions. In most cases, only traces of aldrin were detected. Dieldrin was found in larger amounts, but only in carrots did the residue levels approach the tolerance. Endrin appeared to be absorbed to the same degree as dieldrin. A pronounced influence of soil type on the degree of absorption was apparent. Generally, the residues did not exceed tolerances established for human consumption.

A previous study (Harris *et al.*, 1966a) has established the presence of residues of organochlorine insecticides in agricultural soils in southwestern Ontario. The highest residue levels were found in vegetable, tobacco, and orchard soils. Vegetable and tobacco soils contained residues of the cyclodiene insecticides and DDT. Orchard soils contained DDT, DDE, and dicofol. Although residues were present in the soils, it was not established whether they were sufficiently high to be of any significance. Subsequently (Harris and Hitchon, 1966; Harris *et al.*, 1966a), the cyclodiene insecticide residues were shown to be of significance in so far as the development of cyclodiene-insecticide resistance by soil insects was concerned. Of equal importance, however, was the degree to which these residues in the soil were being absorbed by crops used for either human or animal consumption. It has been well demonstrated elsewhere that some crops are capable of absorbing residues of some organochlorine insecticides from soil. The degree of absorption is dependent on the crop, the specific insecticide involved, its concentration in the soil, soil type, and climate (Lichtenstein, 1965). Crops absorbing the greatest amounts of residues include root crops (Lichtenstein, 1959, 1960; Stewart *et al.*, 1965), other vegetables (Lichtenstein and Schulz, 1965; Lichtenstein *et al.*, 1965), and forage crops (Byrne and Steinhauer, 1966; King *et al.*, 1966; Lichtenstein *et al.*, 1965). The objective of this study was to determine if residues of organochlorine insecticides already present in agricultural soils in southwestern Ontario were sufficiently high to result in residues in agricultural crops. This report summarizes results obtained in the first part of this study, which dealt with some of the more common root crops.

METHODS AND MATERIALS

The experimental plots were set up in four locations in southwestern Ontario: Chatham (A), Fairground (B), Leamington (C), and Strabane (D). The plot located at Chatham served as a control, since no pesticides had been applied to this land and repeated tests indicated that no organochlorine insecticide residues were present in the soil other than a trace (less than 0.01 p.p.m.) of DDT. The remaining areas were selected because a previous study (Harris *et al.*, 1966b) had indicated that these areas contained among the highest residue levels for that particular soil type in southwestern Ontario. Plot A was a Beverly fine sandy loam (2.4% organic matter), plot B a Fox fine sandy loam (1.4% o.m.), plot C a clay (3.6% o.m.), and plot D a muck (66.5% o.m.). The plots, which were 10 × 40 feet, were within the 5-acre sites sampled in 1964 (Harris *et al.*, 1966b).

Soil samples were taken throughout the plot area before planting, so that an accurate picture of residues in the soil could be obtained. Eighty 6-inch cores were taken at random throughout the plot and pooled to form a uniform sample for analysis. On completion of sampling, the following root crops were planted: carrots (Nantes), radishes (Sparkler White Tip), onions (Yellow Sets), and turnips (Laurentian Swede). The varieties were those commonly used in the area. The plot layout was similar in all four locations. Each 40-foot row was subdivided into four 10-foot rows, creating a Latin square arrangement, and the crops were planted on a randomized basis. The plots were seeded between May 12 and 19. They were weeded by hand throughout the growing season. Harvest dates varied, depending on the date of maturity of the specific crop. Radishes were harvested between June 16 and 24, onions from Aug. 3 to 5, carrots from Aug. 13 to 30, and turnips between Sept. 30 and Oct. 12. On completion of the final harvest in October, soil samples were again taken to determine the residue levels in the soil.

Insecticidal residues were extracted from the soils and crops immediately after sampling or harvesting. All adhering soil was removed by thoroughly washing and scrubbing each plant. The crops were macerated with acetone, and the macerate was tumbled for 1 hour with petroleum ether. Both solvents were used in the proportion of 1 ml. per gram of crop. The extracts were then freed of acetone by washing with water, dried, and stored in a freezer until required. The extracts were cleaned up and separated into various fractions on a Florisil column, and then analyzed using gas chromatography and chemical conversion techniques. The procedures for extraction, cleanup, liquid-solid fractionation, and analysis have been described (Sans, 1967).

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Bioactivity of the insecticidal residues in the soil was measured using first instar cricket nymphs [*Gryllus pennsylvanicus* (Burmeister)] as the test organism.

RESULTS AND DISCUSSION

Results of the study are shown in Table I. Analysis of the soil samples prior to seeding indicated that plots B, C, and D each contained a mixture of six to seven organochlorine insecticide residues. Plot B contained 0.20 p.p.m. of DDT (both *o,p'*-DDT and *p,p'*-DDT are consistently found in soils; data reported as DDT represent the sum total of the two isomers) and its metabolites, and 0.73 p.p.m. of the cyclodiene insecticides (aldrin, dieldrin, and endrin). Plot C contained 0.44 p.p.m. of DDT and related materials and 1.41 p.p.m. of aldrin and dieldrin. Plot D, the muck soil, contained 15.38 p.p.m. of DDT and its metabolites, and an extremely high concentration (20.52 p.p.m.) of the cyclodiene insecticides. Bioactivity measurements indicated that the residues in plot C were the most active. Analysis of the soil samples taken on completion of harvesting did not indicate any significant decrease in the residue levels in the soil.

Although residues of DDT were present in the soils in plots B, C, and D, only trace amounts of DDT and DDE were present in the crops. Present Canadian tolerances allow 7.0 p.p.m. of DDT in all the crops involved here. It is generally accepted that DDT is not readily absorbed from the soil by root crops, and this would appear to be the case.

Residues of the cyclodiene insecticides were present in the various crops. Carrots absorbed the most residue, followed by radishes, turnips, and onions, in that order. It has been demonstrated (Lichtenstein, 1959; Stewart *et al.*, 1965) that carrots will absorb greater amounts of insecticide residue than other root crops. The highest aldrin residue, 0.02 p.p.m., was found in carrots grown on the clay soil (plot C). Residues of aldrin in the remaining crops did not exceed 0.01 p.p.m. The present Canadian tolerances for aldrin on all these crops in 0.25 p.p.m.

The tolerances for dieldrin are 0.10 p.p.m. on carrots, radishes, and onions, and 0.25 p.p.m. on turnips. Residues of dieldrin found in carrots on all these plots (B, C, D) were slightly below to slightly above the tolerance. For radishes, turnips, and onions, residue levels were below the established tolerances. No tolerances have been established for endrin in Canada. However, the data in Table I show that endrin may be absorbed by root crops to approximately the same degree as dieldrin. In plot B, which had a very low endrin residue in the soil, no endrin residue was detected in the crops. In plot D, the muck soil, which contained 8.91 p.p.m. of endrin, residues of 0.06 and 0.04 p.p.m. of endrin were detected in the carrots and radishes, respectively.

Lichtenstein (1959) has shown that insecticides are absorbed most readily from light mineral soils and less from muck soils. Recently, Harris (1966) has demonstrated the influence of organic content of the soil on the sorption and inactivation of insecticides. These present data show with considerable clarity (Figure 1) the importance of soil type to

Table I. Residues of Organochlorine Insecticides in Soil and Residues Absorbed by Root Crops

		Organochlorine Insecticide Residues, P.P.M.[a]								
Sample	Soil Type and Crop	DDT	DDE	DDD	Total DDT residues	Aldrin	Dieldrin	Endrin	Total cyclodiene residues	Bio-activity of Soil Sample[b]
A	Sandy loam (control)									
	Before planting	T[c]	T	...	T	...	...	...	...	0
	After harvest	...	...	...	...	...	...	...	...	
	Carrots	...	...	...	...	...	...	...	...	
	Radishes	...	...	...	...	...	...	...	...	
	Turnips	...	...	...	...	...	...	...	...	
	Onions	...	...	...	...	...	...	...	...	
B	Sandy loam									
	Before planting	0.16	0.04	...	0.20	0.12	0.49	0.12	0.73	13
	After harvest	0.14	0.05	...	0.19	0.11	0.48	0.10	0.69	
	Carrots	...	T	...	T	T	0.12	...	0.12	
	Radishes	...	T	...	T	T	0.02	...	0.02	
	Turnips	...	...	...	...	...	0.02	...	0.02	
	Onions	...	...	...	...	...	0.01	...	0.01	
C	Clay									
	Before planting	0.36	0.08	...	0.44	0.53	0.88	...	1.41	87
	After harvest	0.34	0.11	...	0.45	0.48	1.08	...	1.56	
	Carrots	T	T	...	T	0.02	0.11	...	0.13	
	Radishes	T	T	...	T	T	0.05	...	0.05	
	Turnips	...	...	...	...	...	0.03	...	0.03	
	Onions	...	...	...	...	...	0.02	...	0.02	
D	Muck									
	Before planting	14.10	0.64	0.64	15.38	7.74	3.87	8.91	20.52	38
	After harvest	15.13	0.57	0.41	16.11	8.36	3.90	7.07	19.33	
	Carrots	0.01	T	...	0.01	0.01	0.02	0.06	0.09	
	Radishes	0.01	T	...	0.01	T	0.01	0.04	0.05	
	Turnips	T	...	...	T	...	T	...	T	
	Onions	...	...	...	...	...	T	...	T	

[a] P.p.m. calculated on oven-dry weight of soil and fresh weight of crop. [b] Per cent mortality by direct soil bioassay using first instar cricket nymphs as test insects. [c] T = trace = less than 0.01 p.p.m.

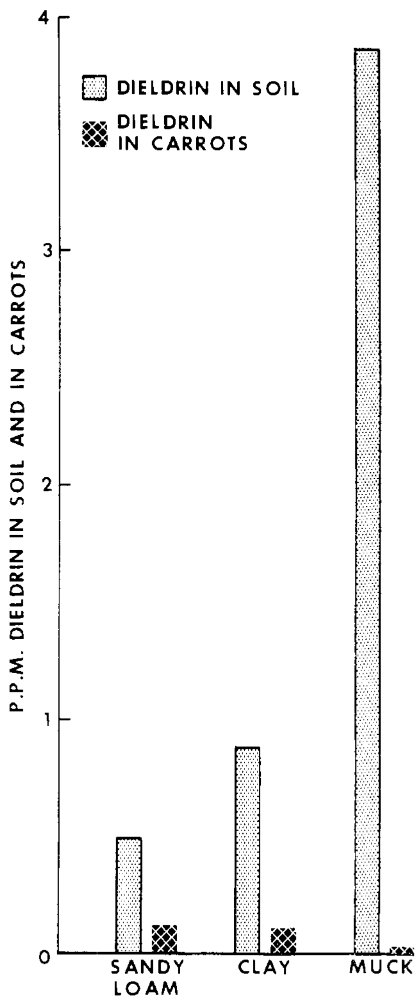

Figure 1. Absorption of dieldrin from soil by carrots in relation to soil type

the degree of absorption of insecticidal residues by crops. Although the muck soil contained 28 and 14.5 times as much cyclodiene insecticide residue as the sandy loam and clay soils, respectively, the residues detected in the crops grown on the muck soil were lower than those found in crops grown on mineral soils. The degree of absorption can also be correlated to some extent with the degree of bioactivity (Table I).

The results of this study indicate that, although residues of organochlorine insecticides are present in agricultural soils in southwestern Ontario, they are not likely to result in residues in root crops greater than the tolerances established for human consumption A possible exception to this rule would be carrots, but the experimental plots were established in areas where the previous survey had indicated that residues of the cyclodiene insecticides were abnormally high. Although the residues in the crops do not exceed the tolerances established for human consumption, in some cases—e.g., turnips—the culls are fed to animals. In these studies, turnips contained from less than 0.01 to 0.03 p.p.m. of the cyclodiene insecticides. Continuous feeding of such crops containing minute amounts of insecticide could result in accumulation of the residue in the animal, with resulting residues occurring in animal products in excess of the tolerances established for human consumption. Consequently, while the residues in the crops are not of direct significance, they may indirectly be of considerable importance.

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