Accumulation of DDT in Soils from Spray Practices

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As recent investigations have indicated that the root systems of certain plants may be injured by excessive amounts of DDT in the soil, information was needed as to the extent of DDT accumulation in soils from spray residues on different crops since 1947, when the application of DDT became a standard practice to control insect pests in orchards and field and vegetable crops. Chemical analyses of soils from four different crops have shown that comparatively large quantities of DDT are accumulating in soils from apple orchards, and relatively small amounts in soils from potato crops. Most of the accumulated DDT was found in the soil layers, corresponding to plow and cultivation depths. The knowledge that DDT tends to accumulate in large quantities in orchard soils will guide the farmer in planting DDT-tolerant crops when old apple trees are removed.

Of the newer pesticides developed during and after World War II, DDT is now the most versatile, universally employed to control many insect pests, ranging from mosquitoes on the wing to grubs in the soil. Its high residual efficiency, comparative safety to man and domestic animals, and low cost have projected it as one of the most useful insecticides. The application of DDT, as sprays and dusts in various formulations, has become a standard practice for insect control in orchards, field crops, and vegetable crops, and in mosquito extermination procedures. As a consequence there has been a growing concern over possible accumulation of DDT in soils in sufficiently large quantities to become harmful to plant growth.

DDT is relatively stable and is only slowly decomposed in the soil (*3*, *12*). Indeed, the ultimate fate of DDT reaching the soil from sprayed crops is still a moot question, engaging the attention of federal and state investigators, farmers, and commercial manufacturers. The interest in this problem is becoming more urgent since results from several investigations indicate that some plants may be injured by DDT.

Review of Literature

Although many grains, orchard trees, corn, and potatoes appear to be very tolerant to DDT, other crops commonly grown in rotation with them are highly sensitive. They include tomatoes, cucumber, spinach, squash, snap beans, strawberries, and some varieties of rye. Not only species of plants but also varieties within the species (*3*, *14*), show differences in their sensitivity to DDT.

Some annual crops showed injury and reduced yields from DDT sprays and dusts (*7*, *18*, *23*, *26*, *29*, *30*, *33*). Other crops were reported injured by various amounts of DDT incorporated directly into the soil (*1*, *2*, *10*, *11*, *13*, *21*, *28*, *34*). Apparently DDT exerts little or no influence on germination and emergence, but some plants become highly sensitive to it after emergence (*3*). Trees and shrubs, being deep rooted, escape injury because DDT does not reach the depth of their roots, whereas some shallow rooting species are unable to establish a sufficient root system for normal growth below the toxic zone (*3*, *14*).

The possible accumulation of DDT in soils from spray practices is of significance in orchards (*1*, *4*, *15*, *17*) and with crops where the green plants are turned under and incorporated in the soil after each harvest, as with potatoes and sweet corn. In apple orchards, for instance, where three or more sprays are applied each season, the total quantity of DDT may be 30 to 50 pounds per acre annually. Moreover, while apple trees appear to be highly tolerant to DDT (*14*), the land may not be kept in orchard continually. When the apple trees are removed, the farmer may be confronted with the problem of either selecting tolerant crops or eliminating the DDT from the soil. Of course, not all of the DDT residue is expected to reach the soil. A large part will be decomposed by sunlight while still on the foliage or on the soil surface (*16*, *20*, *22*). A portion may be washed out by heavy showers. Some of the DDT may decompose in the soil while in contact with certain catalytic agents (*6*, *8*, *9*, *19*).

Considerable investigational work has already been carried out on the persistence of DDT in different soils. Smith (*27*) incorporated DDT in acid and alkaline soils ranging in pH from 5.8 to 8.0. After 18 months of exposure outdoors, about 95% of the original amount of the 2% DDT was recovered in both ranges of soil. Ackley and coworkers (*1*) found from 29 to 81 p.p.m. of DDT in the upper 4 inches of orchard soils. Westlake (*31*) analyzed soils from six apple orchards after 3 years of spraying and reported variations of from 46 to 91 pounds per acre. Fleming (*12*) concludes that DDT in soil undergoes slow decomposition. Foster (*14*) reports that a soil from a peach orchard sprayed annually with 25 pounds of DDT per acre during 1946–49 contained 11 and 127 p.p.m. of DDT between and under trees, respectively. Fleming (*13*) incorporated 25 pounds of DDT per acre in 84 mineral soils and in one muck soil and subjected them to weathering. At the end of 8 years, about 44% of the original DDT remained in the soils, being most persistent in sand and least in muck. The pH within the range of 4 to 7.5 seemed to have no effect.

Allen and coworkers (*2*) incorporated DDT into the top 6 inches of soil at 10 and 20 pounds per acre each spring during five consecutive seasons from 1947 to 1951 and at 40 and 100 pounds per acre in 1947 only. Soil analysis 5 years after application disclosed that of the two single dosages, 38% remained in the soil, whereas about 53% of the total DDT from the five annual applications was recovered.

Materials and Methods

In view of these reports, it became of interest to determine the quantities of DDT that have already accumulated in soils from spray and dust applications on different crops. Preliminary determinations of DDT were made in the spring of 1953 in soils at different depths in apple orchards, corn fields, and potato farms. In 1954, soils from the same

three crops and from peach orchards were sampled, during April and May, only at depths where most of the DDT was found the previous season, generally conforming to the plowing and cultivation practices.

Apple Orchards. The apple orchards were selected in the major apple-growing regions in the state. Each orchard received annually, beginning in 1947, three to four sprays of 1 to 2 pounds of 50 % wettable power DDT per 100 gallons, usually following the recommendations in New Jersey. The soil types encountered were: loam (3), Collington sandy loam (4), and sassafras sandy loam (5). Speed sprayers were employed in all orchards, but the volume of spray per tree varied with the growers and the age of the orchard, ranging from 12 to 25 gallons. Most of the orchards were cultivated regularly to a depth of 3 to 4 inches, but some were kept in sod and only occasionally cultivated. Samples were collected directly under the spread of the branches and in rows between trees. In the preliminary tests during 1953, samples were taken at depths of 0 to 4, 4 to 8, and 8 to 12 inches, but only at 0 to 6 inches in 1954. A standard LaMotte soil sampling tube approximately 1 inch in diameter was used. A representative sample from each of the selected sections of the orchards consisted of six to eight cores under each of 10 trees, crisscrossing from the center trunk to the outer branches, or a total of 60 to 80 cores of approximately 4 to 6 pounds of soil. A similar amount of soil was taken from rows between the trees. The samples were collected in double paper bags and spread in the laboratory to dry. The air-dry soil was pulverized, thoroughly mixed in a mechanical shaker, and stored for DDT analysis. After drying, the soils retained from 3 to 5% moisture. By a similar procedure, samples from peach, corn, and potato soils were obtained.

Cornfields. The cornfields received several sprays or dusts each season, some of them since 1947. In most of these fields, sweet corn is raised annually and the stubble is plowed under, usually to a depth of about 9 inches. In 1953, soil samples were collected at different depths, ranging from 0 to 4, 0 to 9, and 9 to 12 inches; in 1954 the soils were sampled only at 0 to 9 inches, corresponding to the plow depths.

Potatoes. The potato crops received several sprays or dusts of various DDT formulations each season, some dating back to 1946. In 1953, 10 farms were tested where potatoes were grown annually; the soils were sampled at 0 to 9 and 9 to 12 inches. In 1954, 12 farms where a 2-year rotation of potatoes and wheat is practiced (only potatoes receiving DDT) and two farms where potatoes are grown annually were tested at 0 to 9 inches.

Soils from three peach orchards, sprayed with DDT since 1947, were tested in 1954 at 4 and 8 inches.

The chemical determinations of DDT were made by the Schechter colorimetric method (*25*) as modified by Wichman and coworkers (*32*), Downing and Norton (*5*), and Pontoriero and Ginsburg (*24*). The DDT was determined in parts per million of dry soil and calculated in pounds per acre, assuming 2,000,000 pounds for an acre of soil at 6.67 inches.

Table II. DDT Recovered in Soils from Apple Orchards, at 0 to 6 Inches, in 1954

Orchard No.	Description of Orchard	DDT, P.P.M. Under trees	DDT, P.P.M. Between trees
1	New Brunswick, Nixon loam. Several varieties of apple trees, spaced 24 × 20 feet	41.4	13.7
2	South River, Sassafras sandy loam. Large Rome trees, spaced 32 × 24 ft. 20–25 spray gal./tree	42.6	18.0
3	Penn's Neck, Sassafras sandy loam. Rome trees, spaced 40 × 40 feet. 12–14 spray gal./tree	19.4	13.6
4	Same as No. 3, but trees spaced 30 × 30 feet	26.6	10.1
5	Cranbury, Sassafras sandy loam. Rome and Delicious trees, spaced 36 × 36 feet	42.6	26.6
6	Tennant Square, loam. Rome and Delicious trees, spaced 40 × 36 feet	32.3	21.6
7	Freehold, Collington sandy loam. Rome and McIntosh trees, spaced 36 × 36 feet	25.5	20.0
8	Colt's Neck, Collington sandy loam. Rome trees, spaced 40 × 40 feet	36.6	19.4
9	Marlton, Collington loam. Large Rome trees, spaced 40 × 40 feet	33.1	11.1
10	Vincentown, Sassafras sandy loam. Rome trees, spaced 40 × 32 feet	45.0	23.6
	Av.	34.5	17.8

Table I. DDT Recovered in Soils at Different Depths in 1953

Soil Depth, Inches	DDT, P.P.M. Under Trees Min.	Under Trees Max.	Between Trees Min.	Between Trees Max.
	From Apple Orchards			
0–4	31.1	73.0	22.3	51.0
4–8	1.3	25.5	1.1	12.5
8–12	0.4	5.8	0.0	3.7
	Corn Soils Min.	Corn Soils Max.	Potato Soils Min.	Potato Soils Max.
	From Corn and Potato Crops			
0–4	1.9	6.5	...	...
4–8	1.9	3.3	...	...
8–12	1.0	2.6	...	...
0–9	2.4	6.5	1.0	5.1
9–12	0.4	1.9	0.2	1.7

Preliminary Tests in 1953

The data from the preliminary tests conducted at different depths in soils from 12 apple orchards, 10 cornfields, and 8 potato farms are briefly summarized in Table I. DDT residues did not penetrate in soils vertically downward below the plow or cultivation depths. In apple orchards most of the DDT deposits were recovered in the upper 4 inches, corresponding to the average depth of cultivation. Larger amounts of DDT were present directly under the spread of branches than in rows between trees. In soils from the corn and potato crops, practically all of the DDT deposits were located at 0 to 9 inches.

DDT Recovered from Soils in 1954

Apple Orchards. In each of the 10 orchards tested (Table II), considerably

Table III. DDT Recovered in Soils from Peach Orchards in 1954

Orchard No.	Location and DDT Treatment	Depth, Inches	DDT, P.P.M. Under trees	DDT, P.P.M. Between trees
15	Montvale. Sprayed twice each season during 1947–53 with 2 lb. of 50%	0–4	7.5	6.5
		4–8	1.9	1.1
		0–8	9.4	7.6
16	Woodcliff, same treatment as 15	0–4	9.7	4.0
		4–8	0.8	0.6
		0–8	10.5	4.6
17	South River, same treatment as 15	0–4	13.7	4.9

Table IV. DDT in Soils from Potatoes Grown Annually and in 2-Year Rotation, Samples in 1954 at 9 Inches

Farm No.	Location and DDT Treatment	Potato Crop	DDT Recovered, P.P.M.
2	College farm, 2 lb. of 50%/100 gal., sprayed 7 to 8 times each season since 1946	Annual	3.5
7	College farm, sprayed as in 2	Annual	5.4
3	College farm, sprayed as above in 1947–49, 1951, and 1953	2-year rotation	1.9
6	College farm, sprayed as above in 1946–48, 1950, and 1952	2-year rotation	1.7
8	Dayton, dusted with 3% DDT, 30 lb./acre each potato season since 1947	2-year rotation	0.7
9	Dayton, same as 8	2-year rotation	0.9
12	Prospect Plains, same as 8	2-year rotation	1.2
13	Cranbury, 3–5% dust, applied since 1947. Average of four farms	2-year rotation	1.4
28	Monmouth Co., sprayed once or twice during each of four potato seasons with DDT w.p. or emulsion	2-year rotation	0.5
29	Monmouth Co., sprayed once or twice during each of four potato seasons with DDT w.p. or emulsion	2-year rotation	0.5
30	Monmouth Co., same as 28, but treated for six seasons	2-year rotation	1.7

Table V. DDT Recovered in Soils from Sweet Corn at 0 to 9 Inches in 1954

Farm No.	Location and DDT Treatments	Years Treated	DDT Recovered P.P.M.	DDT Recovered Lb./acre
20	Closter, medium clay loam, sprayed with 1.5 lb. 50%/100 gal.	3	2.7	7.3
19	Springfield, heavy clay loam, dusted with 5% DDT	4	3.0	8.1
15	Marlton, sandy loam, dusted with 3–5% DDT	5	3.8	10.3
27	Milltown, dusted with 5% DDT	5	4.7	12.7
16	Burlington, Sassafras sandy loam, dusted with 5% DDT	6	7.1	19.2
17	Florence, Sassafras sandy loam, dusts and sprays	6	7.2	19.4
18	Marlton, Collington sandy loam, dusts and sprays	6	7.0	19.0

higher quantities of DDT were found under the trees than in rows between the trees, corroborating the results from the preliminary tests in 1953. Directly under the branches, the DDT ranged from 19.4 to 45 p.p.m., whereas between the trees the amounts varied from 10.1 to 26.6 p.p.m.

Peach Orchards. Because of the limited number of sprays and smaller size of trees, the accumulation of DDT is much lower in peach soils than in soils from apple orchards. The amounts of DDT (Table III) varied from a minimum of 4.6 p.p.m. between trees to a maximum of 13.7 under trees.

Potato Soils. As many potato growers in New Jersey practice a 2-year rotation of potatoes and wheat, and only the potato crops are treated with DDT, it became of interest to determine the approximate amounts of DDT accumulating in the soils from this practice as compared with annual potato crops. The results (Table IV) reveal comparatively low amounts of DDT, ranging from 0.5 to 1.9 p.p.m. for the 2-year rotation crops. On the other hand, soils from farms 2 and 7, where potatoes were grown annually and had been treated with DDT since 1946, had accumulated from 3.5 to 5.4 p.p.m. of DDT by 1954.

Corn Soils. Analyses of soils from seven cornfields (Table V) indicate that the amounts of DDT recovered vary with the number of seasons that the crop has been treated. The highest accumulation (7.2 p.p.m.) was found in fields sprayed and dusted during six successive seasons, and the lowest (2.7 p.p.m.) was found in soils treated for 3 years.

For the sake of comparison, the total amounts of DDT accumulated per acre of soil from different crops in 1954 are summarized in Table VI. The lowest DDT deposits, 3.2 pounds per acre, were present in potato soils where a 2-year rotation is practiced. This was followed by 12.2 in soils from potatoes grown annually, 9.4 to 19 in peach orchards, 13.7 in corn soils, and 35 to 62 pounds in soils from apple orchards.

Summary and Conclusions

A study was made of the accumulation of DDT in soils from commercial sprays and dusts applied during 1947–53 in apple orchards, peach orchards, cornfields, and potato farms. Representative soil samples were analyzed in 1953 and again in 1954.

The largest quantities of DDT were recovered in soils from apple orchards and the lowest in soils from potato crops where a 2-year rotation is practiced.

In both peach and apple orchards, more DDT was found directly under the trees than between the trees.

Most of the DDT has accumulated in soil horizons corresponding to plow and cultivation depths for each of the four crops—about 4 inches in orchards and 9 inches in soils from corn and potatoes.

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Table VI. Average Amounts of DDT Recovered in Soils from Different Crops in 1954

Crop	Years Treated with DDT	Soil Depth, Inches	DDT Recovered P.P.M.	DDT Recovered Lb./acre
Apple				
Under trees	7	6	34.7	62.2
Between trees	7	6	19.7	35.5
Peach				
Under trees	6–7	8	7.9	19.0
Between trees	6–7	8	3.9	9.4
Potatoes				
Annual	8	9	4.5	12.2
2-year rotation	3	9	1.2	3.2
Corn	3–6	9	5.1	13.7

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Received for review September 21, 1954. Accepted February 1, 1955. Presented before the Division of Agricultural and Food Chemistry, Pesticides Subdivision, at the 126th Meeting of the AMERICAN CHEMICAL SOCIETY, *New York, N. Y., 1954. Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University.*

PESTICIDE TOXICITY

Chronic Toxicity for Rats of Food Treated with Hydrogen Cyanide

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A study of the chronic toxicity to rats of food fumigated with hydrogen cyanide showed that food containing 100 and 300 p.p.m. of hydrogen cyanide produced no signs of cyanide toxicity during a 2-year feeding period. At termination hematological values were within normal limits and neither gross nor microscopic examination of tissues revealed evidence of pathology due to hydrogen cyanide feeding. Definite increases in thiocyanate concentrations were found in the tissues of the experimental animals. The results of this investigation provide data important in the evaluation of the safety and hazards of hydrogen cyanide in view of its varied uses in agriculture and industry.

HYDROGEN CYANIDE has been used for fumigation for almost 60 years, being introduced originally in California for the fumigation of citrus trees infested with scale insects. Coquillet, 1886, is given credit for being the first to suggest its use for destroying insects on plants (*12, 14*).

Since these early investigations the use of hydrogen cyanide as a fumigant has been extended until it now includes the fumigation of dwellings and barracks (*11*) for the destruction of roaches, water bugs, and bedbugs, and the fumigation of warehouses and mills (*7, 8*) against certain insects that destroy food products. The gas has also been employed at ports of entry to combat the introduction of injurious insects from foreign countries (*9, 13*). Some of the more important of these pests are the pink boll worm and the citrus black fly. Fumigation with hydrogen cyanide is also used to prevent the spread of yellow fever (*5*) and bubonic plague epidemics (*6*).

Cyanides are used extensively in electroplating, photography, extraction of precious metals from ores, and case hardening of steel. In these uses there