

# A Survey on DDT-Accumulation in Soils in Relation to Different Crops<sup>1</sup>

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Since 1947, when the application of DDT became a standard practice for insect control in orchards, field and vegetable crops, the fear of accumulating large deposits of this toxicant in soils has been a source of concern to federal and state investigators, farmers, and commercial manufacturers. The ultimate fate of DDT applied to growing crops is still a matter of conjecture. Will it decompose and disappear from the soils, or will its deposits from sprays and dusts continue to increase from year to year and eventually reach quantities harmful to plant growth?

This problem has become more challenging since recent results from several investigations indicate that not all plants are tolerant to DDT. Several crops show distinct injury and growth retardation either from spray applications, Dudley (1947), Gould (1951), Weigel (1951), and Wyle (1952), or as a result of incorporating DDT directly into the soil, Fleming (1947), (1948), Foster (1951), and Thurston (1953). While certain crops commonly treated with DDT appear highly tolerant to it, such as many grains, orchard trees, corn, and potatoes, other crops commonly grown in rotation with them are highly sensitive, such as Rosen and Abruzzi rye, tomatoes, squash, and snap beans.

The possibility of accumulating DDT in soils from spray practices is of greater significance in orchards and with crops where the green plants are turned under and incorporated in the soil after each harvest, as is generally practiced with potatoes and sweet corn. In apple orchards, for instance, where four or more sprays may be applied each season, the DDT residues may amount to 30 to 50 pounds per acre annually. Of course, not all of this quantity is expected to reach the soil. Part of it will decompose by sunlight while still on the foliage or on the soil surface, Lindquist *et al.* (1946), Chisholm *et al.* (1949), Kirk (1952), and Ginsburg (1953). A portion of it may be washed out by heavy showers. Some of the DDT will decompose in the soil while in contact with certain catalytic agents, such as oxides of iron: Fleck & Haller (1945), Fleck (1948), Gunther & Tow (1946), and Downs *et al.* (1951).

A considerable amount of investigational work has already been carried out on the persistence of DDT in different

soils. Smith (1948) incorporated DDT in acid and alkaline soils ranging in pH from 5.8 to 8.0. After 18 months of exposure outdoors, or by controlled leaching in the laboratory, about 95 per cent of the original amount of the DDT has been recovered in both ranges of soil. Ackley *et al.* (1950) have analyzed soils from apple orchards in the Wenatchee and Yakima areas in Washington, sprayed for several years with DDT, and found variations of from 29 to 81 p.p.m. of DDT in the upper 4 inches of soil. Westlake (1950) analyzed soils from six apple orchards after 3 years of spraying and reported variations from 46 to 91 pounds per acre. Fleming *et al.* (1951), after recovering about 30 per cent of the total DDT incorporated in field plots about 6 years after treatment, concludes that DDT in soil undergoes a slow rate of decomposition. Foster (1951), reports that a soil from a peach orchard sprayed annually with 25 pounds of DDT per acre during 1946-49 contained at 3 to 4 inch depth 11 and 127 p.p.m. DDT between and under trees, respectively. Fleming & Maines (1953) 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 per cent 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.

In general, the results previously reported seem to indicate that DDT does not readily decompose in most of the cultivated soils and may, after repeated annual applications, remain in sufficiently large quantities to interfere with the growth of certain crops.

The purpose of this investigation is two-fold: First, to determine the quantities of DDT that have already accumulated in New Jersey soils from spray and dust applications on different crops, and Second, to conduct periodic or annual analyses of the soils in order to secure information on the rate at which DDT deposits continue to increase as a result of successive annual spray applications.

**MATERIALS AND METHODS.**—Soils from 12 apple orchards, 8 potato farms, 10 sweet corn fields, and 1 cranberry bog were analyzed for DDT in 1953. The apple orchards were selected in the major apple growing regions in the state. Each orchard received annually, since 1947,

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three to four sprays of DDT, 50 per cent W.P. at 1 to 2 pounds 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. Most of the orchards were cultivated regularly to a depth of 3 to 5 inches, while some were kept in sod and only occasionally cultivated. Representative sections in each orchard were selected in consultation with the grower. Samples were collected under the spread of branches, approximately 4 to 6 feet (depending on the size of the tree) from the main tree-trunk and in rows between trees at three depths, —0 to 4 in., 4 to 8 in. and 8 to 12 in. A standard LaMotte soil sampling tube approximately 1 inch in diameter was used. A sample consisted of 4 to 6 cores around each tree, from about 10 trees per section. The samples were collected in paper bags, and the heavy clumps were broken up and allowed to dry in the laboratory. The air-dried soil was then thoroughly mixed and stored for chemical analyses. By a similar procedure, soil samples from the other three crops were collected.

The potato farms received several applications of sprays or dusts of various DDT formulations each season since 1946. In each of the selected farms, potatoes were grown annually and cultivated to a depth of about 9 inches. The vines were

plowed under after harvest. The soils were sampled at depths of 0 to 9 and 9 to 12 inches.

The corn fields received several applications of sprays and dusts each season since 1947. Sweet corn was grown annually, and the stubble was plowed under to a depth of 9 to 10 inches. In four farms the soils were sampled at depths of 0 to 4, 4 to 8, and 8 to 12 inches, whereas in the other six farms, samples were collected only at two depths namely, 0 to 9 and 9 to 12 inches. Eight of the soils were sandy loams and two were clays.

One cranberry bog was analyzed at depths of 0 to 4, 4 to 8, and 8 to 12 inches. The cranberries in this bog received an average of two dusts and two sprays each season since 1947. At the time of sampling, June 11, 1953,<sup>2</sup> the records showed 13 dustings and 12 sprays. The total amount of actual DDT applied on this bog during the entire period was about 85 pounds per acre.

The DDT-analyses were made by the colorimetric method of Schechter *et al.* (1945) as modified by Wichman *et al.* (1946), Downing & Norton (1951), and Pontoriero & Ginsburg (1953). Three hundred gm. of soil were extracted with 300 ml. of benzene by shaking for about 30 minutes. The filtrates were decolorized by shaking for 5 to 10 minutes, as required, with about 5 gm. of a mixture containing four parts filter cell and two

<sup>2</sup> These samples were obtained through the efforts of Dr. O. Starnes.

Table 1.—DDT recovered from soils in apple orchards sprayed during 1947-1952.

ORCHARD No.	LOCATION AND DESCRIPTION OF ORCHARD	PART OF ORCHARD	SOIL DEPTH, INCHES	DDT-RECOVERED	
				P.P.M.	Pounds/Acre
1	New Brunswick Nixon loam Medium size trees of different varieties, spaced 24×20 ft. Occasionally cultivated to a depth of 3 to 4 inches.	Under trees	0-4	63.7	76.5
			4-8	1.4	1.6
			8-12	0.4	0.5
		Between trees	0-4	29.8	35.8
			4-8	3.4	4.0
			8-12	0.1	0.1
					78.7
					39.9
2	South River Sassafras sandy loam Large Rome trees spaced 28×32 ft. Cultivation 4 to 5 inches deep. 20-25 spray gal. per tree.	Under trees	0-4	73.0	87.6
			4-8	19.8	23.7
			8-12	1.9	2.3
		Between trees	0-4	39.2	47.0
			4-8	9.3	11.2
			8-12	0.0	0.0
					113.6
					58.2
3	Penn's Neck Sassafras loam Large Rome trees spaced 40×40 ft. Soil kept in sod, rarely cultivated, no cover crop. 12-14 spray gal. per tree.	Under trees	0-4	25.3	30.4
			4-8	3.0	3.6
		Between trees	0-4	16.0	19.24
					34.0
4	Same as No. 3, but the trees are spaced 30×30 ft. 12-14 spray gal. per tree.	Under trees	0-4	37.5	45.0
			4-8	6.1	7.3
		Between trees	0-4		
			8-12		
					52.3
					16.0

ORCHARD No	LOCATION AND DESCRIPTION OF ORCHARD	PART OF ORCHARD	SOIL DEPTH, INCHES	DDT-RECOVERED			
				P.P.M.	Pounds/Acre		
5	Cranbury Sassafras sandy loam Several varieties planted in 1932. Spaced 30×36 ft. Cultivation 3 to 4 inches deep. Rye cover crop, Straw-mulch. About 20 spray gal. per tree.	Under trees	0-4	55.1	66.0	70.0	
			4-8	3.9	4.7		
		Between trees	0-4	21.2	25.4		26.7
			4-8	1.1	1.3		
6	Tennent Square, Freehold Loam Several varieties planted in 1930. Spaced 40×36 ft. Cultivation 3 to 5 inches. Hay mulch. Vetch cover crop. About 17 spray gal. per tree.	Under trees	0-4	44.3	53.2	61.8	
			4-8	4.6	5.5		
			8-12	2.6	3.2		
		Between trees	0-4	21.2	25.4		38.2
			4-8	6.9	8.2		
			8-12	3.7	4.5		
7	Freehold Collington sandy loam Rome & McIntosh planted in 1928. Spaced 36×36 ft. Cultivation 3 to 4 inches. Vetch cover crop or left in sod.	Under trees	0-4	31.5	37.8	61.5	
			4-8	7.5	9.0		
		Between trees	0-4	38.6	45.3		46.8
			4-8	18.5	16.2		
8	Colts Neck Collington sandy loam Rome & McIntosh planted 1928. Spaced 36×36 ft. Cultivation 3 to 4 inches deep or left in sod. No cover crop.	Under trees	0-4	54.7	65.6	84.5	
			4-8	14.9	18.8		
		Between trees	0-4	31.3	37.6		38.7
			4-8	1.0	1.2		
9	Marlton Collington loam Red Rome planted 1912. Spaced 40×40 ft. No cultivation. No cover crop.	Under trees	0-4	48.1	51.7	64.7	
			4-8	5.1	6.1		
			8-12	5.8	6.9		
		Between trees	0-4	15.8	18.9		
10	Vincentown Sassafras sandy loam Red Rome planted in 1919. Spaced 40×32 ft. Cultivation 4 to 5 inches deep. No cover crop.	Under trees	0-4	31.5	37.8	47.9	
			4-8	8.5	10.1		
		Between trees	0-4	21.1	25.4		35.0
			4-8	8.8	10.5		
11	Marlton Pike Collington fine sandy loam Rome trees spaced about 24×24 ft., culti- vated. No cover crop.	Under trees	0-4	34.7	41.7	72.3	
			4-8	25.5	30.6		
		Between trees	0-4	18.9	22.6		37.6
			4-8	12.5	15.0		
12	Masonville Sassafras loamy sand Trees 40 years old, spaced 40×40 ft., were re- moved in 1951. The soil was then plowed to a depth of 9 inches and tomatoes planted in 1952. Poor growth observed in places where the trees stood.	In places where trees stood	0-9	13.9	37.50	44.3	
			9-12	7.6	6.82		
		Between trees	0-9	9.9	26.7		

Table 2.—Average DDT in Orchard Soils at Different Depths.

SOIL DEPTH (Inches)	POUNDS OF DDT PER ACRE			
	Under Trees		Between Trees	
	Min.	Max.	Min.	Max.
0-4	37.7	87.6	26.7	61.5
4-8	1.6	30.6	1.3	15.0
8-12	0.5	6.9	0.0	4.5
0-12 (total)	35	113	26	61

parts *Nuchar*. Aliquots of the clear filtrates were used for analyses. The photometric densities of *p,p'*-DDT were measured on the Fischer electrophotometer at a wave length of 580 m $\mu$  (Filter #58) and compared with a standard curve of *p,p'*-DDT, similarly developed, from technical DDT.<sup>3</sup> The average results of the chemical analyses as well as a brief description of each soil and treatment are presented in six tables.

**RESULTS.—DDT in Apple Orchard Soils.**—The results, presented in table 1, brought out the following information. In 11 of the 12 orchards tested, larger quantities of DDT have accumulated in soils under the spread of branches than in rows between trees. Only in one or-

chard (No. 7), the results were reversed. In all orchards, most of the DDT was found in the upper 4 inches of soil, corresponding to the average depth of cultivation. Small quantities were recovered in 4 to 8 inches depths and still smaller amounts at the 8 to 12 inches depths. The average total DDT recovered from all depths (Table 2) in any single orchard, measured in pounds per acre, varied from 35 to 113 under trees and from 26 to 61 between trees.

**DDT in Potato Soils.**—The total amount of DDT recovered in this group of soils (Table 3) varied from a minimum of 3.8 to a maximum of 14.7 pounds per acre. Practically all of the DDT was present in the 0 to 9 inch layer of soil or plow depth, and very little at the 9 to 12-inch layer. Apparently DDT does not penetrate vertically downward, unless plowed in or other wise mechanically mixed. It should be pointed out here that the lowest quantities of DDT deposits were recovered in the five soils where sprays of DDT emulsion were applied, giving a narrow range of 3.8 to 5 pounds per acre. On the other hand, the highest amount (14.7 pounds) was found in soil No. 6

<sup>3</sup> Mr. S. Buckser assisted in the chemical analyses.

Table 3.—DDT deposits in soils from potato crops, sprayed during 1946-52.

FARM No.	LOCATION AND DDT APPLICATIONS	SOIL DEPTH (Inches)	DDT-RECOVERED	
			P.P.M.	Pounds/Acre
1	Salem. Sandy loam. 25% DDT emulsion, 1 quart per 100 gal. (0.5 lb. DDT). From 5 to 7 sprays were applied each season during 1947-52, cultivated to 9-10-inch depth.	0-9	1.5	4.0
		9-12	0.6	0.5
				4.5
2	Elmer <sup>1</sup> Sassafras loamy coarse sand.	0-9	1.7	4.5
		9-12	0.2	0.2
				4.7
3	Elmer <sup>1</sup> Sassafras loamy coarse sand.	0-9	1.0	2.7
		9-12	1.2	1.1
				3.8
4	Salem <sup>1</sup> Sandy loam	0-9	1.5	4.0
		9-12	1.1	1.0
				5.0
5	Freehold <sup>1</sup> Monmouth loam	0-9	1.8	4.5
		9-12	0.4	0.4
				4.9
6	New Brunswick. Sassafras sandy loam. 50% W.P., 2 lbs./100 gal. Sprayed 125 gal. per acre, 7-8 times each season during 1946-52. Cultivation to 9-inch depth.	0-9	5.1	13.8
		9-12	1.0	0.9
				14.7
7	Cranbury. Sassafras sandy loam. As No. 6, but applied only during 1946-51.	0-9	2.9	7.8
		9-12	0.4	0.4
				8.2
8	Freehold. Sassafras sandy loam. Dusted with 3% DDT by airplane during 1946-50. Sprayed as in No. 6 during 1951-52.	0-9	3.4	9.2
		9-12	1.7	1.5
				10.7

<sup>1</sup> Same treatments and cultivation as Farm No. 1.

Table 4.—DDT found in soils from corn crops sprayed and dusted during 1947-52.

FARM NO.	LOCATION AND DDT APPLICATIONS	SOIL DEPTH (Inches)	DDT-RECOVERED	
			P.P.M.	Pounds/Acre
11	Bridgeboro. Sandy loam. 5 applications annually of 1-2 lbs. DDT/acre. Dusts were used in 1948-49-50 and sprays in 1951 and 1952.	0-4	4.2	5.0
		4-8	3.3	4.0
		8-12	2.2	2.6
				11.6
12	Salem. Dusted 5 times each season with 1-2 lbs. DDT/acre during 1948-52.	0-4	4.0	4.8
		4-8	3.3	4.0
		8-12	2.6	3.2
				12.0
13	Same as No. 12.	0-4	2.0	2.3
		4-8	2.0	2.3
		8-12	1.0	1.2
				5.8
14	Same as No. 12.	0-4	2.5	3.0
		4-8	1.8	2.2
		8-12	1.3	1.5
				6.7
15	Marlton. Evesboro sandy loam. 1948-49—3% dust, 35 lbs./acre, 4 applications yearly. 1950-52—5% dust, 35 lbs. per acre, 4 applications yearly. 1951-52—4 extra applications of 5% dust on broccoli.	0-9	3.4	9.2
		9-12	1.0	0.9
				10.1
16	Burlington. Sassafras sandy loam. 1947-48—3% dust, 50 lbs./acre, 3 or more applications per year. 1949-52—5% dust, 50 lbs./acre, 4 applications annually.	0-9	6.5	17.4
		9-12	1.9	1.7
				19.1
17	Florence. Sassafras sandy loam. 1947-49—3% dust, 50 lbs./acre. 1950-51—5% dust, 50 lbs./acre, 5 applications per year. 1952—2 sprays of 2 lbs. 50% W.P. per 100 gals. per acre.	0-9	6.5	16.4
		9-12	0.7	0.6
				17.0
18	Marlton. Collington sandy loam. 1946-47—3% dust, 50 lbs./acre, 4 applications each year. 1948-52—5% dust, 50 lbs. per acre, 5 applications annually. 1949—no treatment.	0-9	6.3	17.0
		9-12	0.5	0.5
				17.5
19	Springfield. Heavy clay. 1949-52—5% dust, appl'd 5-6 times each year at 35 lbs./acre.	0-9	2.7	7.3
		9-12	1.0	0.9
				8.2
20	Closter. Medium clay loam. 1951—5 sprays of DDT emuls. at 1.5 lbs./acre. 1952—3 sprays of the same. Total=12 lbs. DDT/acre.	0-9	2.4	6.8
		9-12	0.4	0.4
				6.9

where DDT-W.P. sprays were used. In the emulsion formula only 0.5 pound of actual DDT per 100 gal. was used as compared with 1 pound of actual DDT in W.P. form.

**DDT in Corn Soils.**—Rather large variations (Table 4) were encountered in this group of soils, ranging from 5.8 to 19.1 pounds of DDT per acre. As in the potato soils, the greatest amount of DDT accumulated within the plow depth layer of 0 to 9 inches. This fact is brought out even more clearly when the soil analyses from farm Nos. 11, 12, 13 and 14, where three depths were sampled, are examined. The middle layer of 4 to 8 inches yielded almost as much DDT as the surface layer of 0 to 4 inches, whereas the lowest layer of 8 to 12 inches contained much less DDT than the upper layers, but considerably more than the 9 to 12-inch depths in the

soils from farm Nos. 15 to 20 inclusive. Evidently the layer of soil at 8 to 9 inch, which was still within the plow depth, is responsible for the higher amounts of DDT recovered from the 8 to 12 inch depths in the first four soils, as compared with the 9 to 12-inch depths in the other six soils. In this respect, no differences were apparent between the two clay soils, Nos. 19 and 20, and the four sandy loam soils, Nos. 15, 16, 17, and 18. In each case, regardless of soil type, practically all of DDT remained within the plow depth layer, again indicating no vertical downward movement of DDT.

**DDT in Cranberry Bog Soil.**—The results show a total of 34.5 pounds of DDT recovered out of an approximate gross total of 85 pounds applied since 1947. Applications of DDT were started in this bog in 1947 and continued to date of sam-

pling in 1953. Each year about two applications of dust and two of sprays were applied. A total of 13 applications of 5 to 1 per cent DDT at 50 pounds per acre and 11 applications of 50 per cent wettable powder at 5 pounds per acre and one application of 50 per cent wettable pow-

Table 5.—Average amounts of DDT in soils from different crops.

CROPS	POUNDS OF DDT PER ACRE		Avg. total of all soils
	Min.	Max.	
Potatoes	4	15	7
Corn	6	19	11
Cranberries	—	34	—
Apple Orchards			
Under trees	35	113	34
Between trees	26	61	33

der at 8 pounds per acre were made. As in the other three groups of soil, most of the DDT (32 pounds) was located in the upper 4 inches, little (2.5 pounds) at 4 to 8 inches, and none at 8 to 12 inches. Even in this light, fluffy type of soil, the DDT did not penetrate downward to any appreciable extent below the cultivation depth of 4 inches.

**Discussion.**—The variations in the quantities of DDT recovered within each group of soil may be ascribed to one or more of the following factors: DDT formulations employed; number of sprays or dusts applied per season; methods of application; total amount of DDT applied per acre; soil topography, and climatic conditions. In orchard soils, the number of trees per acre, size of trees, and the gallonage applied per tree with each spraying are also contributing factors. In the apple orchards tested, the amounts applied per tree with each spray varied from 12 gallons in orchard No. 3, where the DDT deposits in the soil were comparatively low, to about 25 gallons in orchard No. 2, where high DDT deposits were found. Apparently the type of soil has not played any significant part in the DDT accumulation.

For the sake of comparison, the overall average total DDT found per acre of soil from different crops are summarized in table 5. The lowest DDT deposits, 7 pounds per acre, were present in potato soils. This was followed by 11 pounds in corn soils; 34 pounds in the cranberry bog, and 54 pounds in soils from apple orchards.

**SUMMARY AND CONCLUSIONS.**—A study was made on the accumulation of DDT deposits in soils from 12 apple orchards, 10 corn fields, 8 potato farms, and 1 cranberry bog as a result of commercial spray and dust applications for insect control during the last 6 years. Samples of soils, collected at different depths, were analyzed for DDT and brought out the following:

In soils from apple orchards the DDT ranged, in pounds per acre, from 35 to 113 under trees and from 26 to 61 between trees. Most of the DDT was found in the upper 4 inches of soil, corresponding to the average depth of cultivation, small quantities in 4 to 8 inch-depths, and low amounts at 8 to 12-inch depths.

The cranberry bog contained a total of 34.5 pounds of DDT per acre, of which 32 pounds were present in the upper 4 inches of soil.

In corn soils, the total DDT ranged from 5.8 to 19, or an average of 11 pounds per acre.

The lowest deposits of DDT were found in potato soils ranging from about 4 to 15, or an average of 7 pounds per acre.

Practically all of the DDT recovered in both potato and corn soils was located at 0 to 9-inch layers, corresponding to the average plow depth.

Generally the results indicate that DDT residues do not penetrate vertically downward below the plow and cultivation depths.

The soil type in this investigation, ranging from loamy sand to heavy clay, did not play any significant role in the amount of DDT retained from the spray and dust residues.

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