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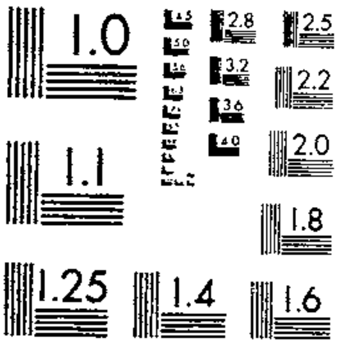

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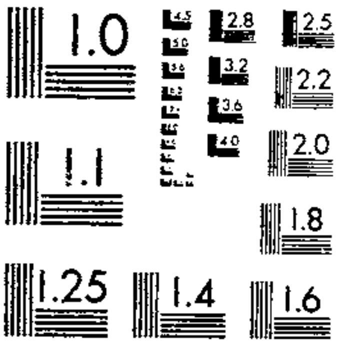

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UNITED STATES DEPARTMENT OF AGRICULTURE
In Cooperation with
NEW JERSEY AND MISSISSIPPI AGRICULTURAL EXPERIMENT STATIONS

CONTENTS

Substantial contributions to this study were made by many individuals in various research units of the United States Department of Agriculture and of the New Jersey and the Mississippi Agricultural Experiment Stations. The wide scope of the work was made possible in part by the cooperation of the Agricultural Chemicals Division of the Shell Chemical Corp.

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Some Effects of

INSECTICIDE SPRAY ACCUMULATIONS IN SOIL ON CROP PLANTS[1]

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United States Department of Agriculture in cooperation with the State agricultural experiment stations of New Jersey and Mississippi

PURPOSE AND BACKGROUND

Much of the earlier work, between 1945 and 1950, on possible harmful effects of residues of chlorinated hydrocarbon insecticides in the soil was based on single direct additions of the substances to soils, followed by determinations of effects on successive crops grown on the treated soils. That general method gives valuable information on the tolerance of specific plants to various amounts of the insecticides in different soils and, over a period of years, indicates the relative persistence of any effects due to the residues of the added substances. That procedure, however, will not indicate how fast an insecticide is likely to accumulate in a soil following repeated applications to crops—it only shows what may happen after a given quantity has accumulated.

Early experience with DDT in orchards indicated that because of its great stability it tended to accumulate in the surface soil beneath the trees at a rate almost equal to its rate of application per acre annually.[3] Some other chlorinated hydrocarbons, however, are less stable than DDT and therefore accumulate less rapidly. Not only the rate of decomposition in the soil but also the tendency of the insecticide to decompose or volatilize before it reaches the soil affects the degree to which the insecticide may accumulate. Obviously, too, the removal of the harvested crop or crop residue may carry away some of the insecticide applied, preventing that part of it (or its decomposition products) from reaching the soil.

Studies of plant reactions to soil applications of chlorinated hydrocarbon insecticides were started at the Plant Industry Station, Beltsville, Md., in 1945.[3] Incidental to those studies, small plots on greenhouse benches were set up in 1949 to obtain preliminary information on accumulation of several insecticides in the soil following foliage applications as sprays. Additional and larger spray-accumulation plots were set up in coldframes the following year, and a still more comprehensive set of outdoor plots was established in 1951. In 1952 extension of this last design into two other States became possible through the cooperation of State and private agencies.

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[1] Submitted for publication February 14, 1956.

[2] Died May 26, 1954.

[3] Foster, A. C. Some plant responses to certain insecticides in soil. U. S. Dept. Agr. Cir. 862, 41 pp., illus. 1951.

GENERAL METHODS

PRELIMINARY DESIGNS AT BELTSVILLE, MD.

GREENHOUSE PLOTS

Duplicate plots, approximately 2½ by 3 feet, were arranged on benches next to the walls of an even-span greenhouse, 35 feet wide and with eaves 6 feet above the floor. The benches contained Evesboro sandy loam soil to a depth of 6 inches. Chlorinated hydrocarbon insecticides and isomers thereof were sprayed repeatedly on foliage of successive plantings of a wide range of crop plants, including vegetable plants, cereal plants, and soybeans. During spray applications, adjacent plots were protected from drift by a high portable shield at the sides and back of the plot being sprayed.

The insecticides were each applied as carefully weighed quantities of wettable powder suspended in sufficient water to cover the plants in each plot thoroughly with a minimum of runoff. A small portable paint-gun outfit was used for spraying, with appropriate atomizer-type nozzles and a separate container for each formulation. Efforts were made to deliver the spray materials quantitatively to the plants and to the area they occupied, but some of the material was probably lost on the shield or by drift at the unprotected front of the bench.

Because of limited space and crowding, the plants of these very small plots were harvested while still small. Green weights of aboveground parts were recorded. The plants were then returned to the plots and worked into the soil.

Over a period of nearly 4 years a gradually increasing and finally troublesome salt content developed in the soil in the greenhouse benches at Beltsville. This was rather emphatically brought to light by excessively high organic chlorine blanks of the plots that had received no insecticide at any time. Although we have noted no reference to organic fixation of inorganic chlorine in soil, our continued use of chlorinated water from the local public supply appeared to be interfering with determinations of organic chlorine content of the soil.

Conductivity readings of the treated and nontreated soils, made with a Model RD–15 Solu Bridge soil tester, revealed very high total salt content. Periodic applications of commercial fertilizer as well as heavy use of chlorinated water doubtless contributed to the addition of salts to the soil. Heating pipes below the benches and moderate greenhouse temperatures combined to produce a relatively high demand for water the year around. Avoidance of excessive watering of the beds resulted in virtually no leaching of the salts added in water and fertilizer.

Accompanying the development of the high salt condition, attacks of *Rhizoctonia* and other fungi were increasing, interfering with establishment of uniform stands and with growth. Further, some of the effects of insecticide treatments appeared to be rather more serious than in our other experience. Efforts to reduce salt content by leaching the soils in place in the benches were unsatisfactory. In the early autumn of 1953, therefore, the soil from all plots was removed from the greenhouse to shallow, open beds for prolonged leaching by rain and melted snow. The soil was spread over wire screen lying on a very well-drained gravelly area, and the several lots kept separate by wood partitions.

Upon return of the soil to the benches in the spring of 1954, the salt content had been reduced to a normal level and much improved plant growth resulted. The trouble described here has not developed in outdoor tests.

The chlorinated hydrocarbon insecticides are highly insoluble in water, therefore, they are not leached readily from the soil.

COLDFRAME PLOTS

In order to include studies of additional substances and to obtain space for growing plants to larger size, another duplicate series of spray-accumulation plots (1949–54) was established outdoors in coldframes built of cinder blocks and designed to be covered with standard 3- by 6-foot sash. Single plots were approximately 3 by 6 feet, separated at first by boards 1 foot wide shoved edgewise into the soil about 8 inches; later the boards were replaced by sheets of asbestos-cement one-quarter inch thick.

Methods of treatment and handling of test plants were essentially as described for the greenhouse plots, except that some of the smaller growing crops such as snap beans were harvested in a normal manner and the crop residue only turned into the soil after weighing.

CHEMICAL ANALYSES

To determine the tendency of an insecticide or its chlorinated decomposition products to accumulate in the soil of the sprayed plots, soil samples were analyzed for organic chlorine and the results calculated to equivalents of the respective substances applied.[4] Soil samples were taken from points well distributed over each plot to the depth of the treated soil and composited for each plot.

Unfortunately, resources were available for few determinations of organic chlorine content of plant tissues associated with treatment. Two crops of carrots and one of turnips at Beltsville were so analyzed by the Entomology Research Branch. Turnips from some of the State College, Miss., plots and carrots from some Beltsville plots were analyzed for specific insecticides in the laboratories of the Shell Chemical Corp. Turnips and sweetpotatoes of the State College plots were also analyzed at that location.

After harvest of the carrot crop July 16, 1953, the roots were washed on a screen in water running from a hose. Soil not immediately washed off by the water alone was rubbed loose with the hands and the roots were rinsed.

Until a taste panel could judge the roots, the carrots were stored in paper bags for a few days at 38° F. To preserve the samples for later analysis they were quick-frozen and so held for about 2½ months, when they were analyzed for total organic chlorine. The difference between the lots from treated plots and the controls was calculated to equivalent amounts of the respective insecticides. For comparative

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[4] KOBLITSKY, L., and CHISHOLM, R. D. DETERMINATION OF DDT IN SOILS. Assoc. Off. Agr. Chem. Jour. 32: 781–786. 1949.

purposes, the insecticide content of the soil is shown, assuming the accumulated residues to be mixed throughout the surface foot in the beds.

Samples from the 1954 crops of carrots and turnips were washed and kept in cold storage (not frozen) a few days until they were analyzed. The 1953 crop of carrots, which had been frozen and stored, was in poor condition when analyzed. Freezing, storage, and thawing, followed by the necessary drying to remove condensed matter before extraction, resulted in considerable dehydration and decomposition so that the parts per million (p. p. m.) calculated on a weight basis taken at that time was considerably higher than it would have been on freshly harvested roots. The 1954 crop was extracted for analysis in the recently harvested undried condition.

COOPERATIVE DESIGNS, 1951-54

SOILS AND PLOT ARRANGEMENT

The soil used in the work at Beltsville, Md., is Congaree loam, a fertile, friable, brown soil containing noticeable amounts of mica. It was removed from the surface 6 to 7 inches of the flood plain of a small creek that flows through the Plant Industry Station and placed to a settled depth of 9 inches in 6- by 6-foot compartments built of cinder blocks. These compartments were arranged in 2 rows of 22 each, with the walls extending 10 inches below and 6 inches above ground level and the compartments were provided with tile drainage. The substrate below is compact gravelly fill unsuited to plant growth. Sprinkler irrigation was provided.

At State College, Miss., 8- by 10-foot plots were arranged on Kaufman sandy loam in a good state of fertility, with depressed alleys 2 feet wide between plots. Sprinkler irrigation was available.

At New Brunswick, N. J., 6- by 8-foot plots were arranged on Sassafras sandy loam (pH 6.0 to 6.2) with 2- by 8-inch boards separating the plots. The boards were placed edgewise with about 4 inches below the soil surface. Before establishment of the plots and installation of the board barriers between plots, the soil was deeply plowed and harrowed in conventional manner. After the boards were placed between plots, 5–10–5 fertilizer was broadcast on each plot at the rate of 1,200 pounds per acre and thoroughly mixed into the upper 4 inches of soil with a potato fork. After the initial preparation of the soil all work was done by hand. Fertilizer was added and worked in each year as stated above.

All working of the soil at Beltsville and New Brunswick was done with hand tools, and care was taken to avoid contamination of any plot by transfer of soil into it from another. The plots at State College were prepared and reworked each spring with a small rotary tiller.

At all locations the treatments were arranged at random in each of four blocks and the data were analyzed by the variance method for randomized blocks.

CROPS AND CROPPING SYSTEMS

Because of differences in climate and soil among the three locations, the test crops grown differed widely. Each investigator grew crops well adapted to the respective conditions and that could best be handled along with other work to be done during the year. Table 1 shows the times of planting and of harvest of the several crops grown at each location.

Root crops were harvested by pulling the entire plants and removing both roots and tops from the plots. Of other crops, only those portions normally marketed were removed from the plots, although the entire aboveground parts were removed for weighing. Those parts of the plants that normally are not removed from the field were, after weighing, spread back on the plots on which they grew and worked into the soil.

A diversity of crops was grown to obtain information on possible responses to as many different crops as feasible. Although major interest in this work was centered around crop response to residues accumulating in the soil, any evidence of direct injury by the foliage application was noted.

TABLE 1.—*Dates of planting and of final harvest of test crops grown at different locations, 1951–54*

Location and test crop grown	Date	
	Planted	Harvested
Beltsville, Md.:		
Spinach, Old Dominion	Sept. 5, 1951	Oct. 17, 1951
Oats, Lee	do	Nov. 23, 1951
Pea, Thomas Laxton	Mar. 18, 1952	June 10, 1952
Bean, Stringless Black Valentine	June 24, 1952	Sept. 3, 1952
Radish, Scarlet Globe	Sept. 18, 1952	Oct. 28, 1952
Rye, Abruzzi	Oct. 28, 1952	Apr. 15, 1953
Carrot, Imperator and Danvers Half Long	Apr. 27, 1953	July 16, 1953
Rye, Abruzzi	Sept. 11, 1953	Jan. 8, 1954
Carrot, Imperator	Apr. 21, 1954	July 20, 1954
Bean, Stringless Black Valentine	Aug. 13, 1954	Oct. 4, 1954
State College, Miss.:		
Bean, Tendergreen	Aug. 24, 1951	Oct. 29, 1951
Turnip, Seven Top	Jan. 17, 1952	Apr. 25, 1952
Southern pea, Dixielee	May 26, 1952	Aug. 5, 1952
Bean, Contender	Aug. 12, 1952	Oct. 18, 1952
Turnip, Seven Top	Jan. 18, 1953	May 2, 1953
Southern pea, Dixielee	June 8, 1953	Aug. 14, 1953
Bean, Contender	Aug. 17, 1953	
Turnip, Purple Top White Globe	Jan. 8, 1954	May 19, 1954
Sweetpotato, Allgold	June 4, 1954	Nov. 12, 1954
New Brunswick, N. J.:		
Bean, Stringless Black Valentine	May 24, 1952	July 23, 1952
Do	Aug. 2, 1952	Sept. 27, 1952
Do	June 1, 1953	Aug. 10, 1953
Do	Aug. 15, 1953	Oct. 11, 1953
Do	May 15, 1954	July 26, 1954
Do	Aug. 5, 1954	Oct. 9, 1954
Carrot, Chantenay	Aug. 2, 1954	Nov. 27, 1954
Turnip, Purple Top White Globe	Aug. 6, 1954	Dec. 5, 1954

INSECTICIDES AND APPLICATION

The basic design of the work included nine insecticides—aldrin, dieldrin, isodrin, endrin, heptachlor, chlordane, Dilan, BHC, and toxaphene—that were either in current use or that had shown some promise of commercial use. Table 2 shows these along with several others variously included by one participant or another because of special interest in them. The table also shows the formulation from which each spray treatment was prepared, and the rate per acre at which each pure insecticide equivalent was applied at each spraying.

Details of method of application of sprays differed among locations according to equipment that was available. All operators isolated adjacent plots from the plot being sprayed by surrounding the latter completely with a portable cloth or plastic screen that extended from the soil to a height of approximately 3½ feet. Care was taken to confine treating materials to the areas designed to receive them.

At Beltsville and New Brunswick the sprays were applied with small engine-driven compressed-air paint-spray outfits equipped with atomizer-type nozzles that produced good coverage with a medium to coarse spray. Accurately weighed quantities of the wettable powders required for single plots were weighed into small containers designed for attachment to the spray gun. Enough water was used to give good coverage of the foliage with a minimum of runoff, and the entire weighed quantity of insecticide was applied to each plot. The gun and containers were washed with water after use of each formulation.

TABLE 2.—*Insecticides and rates of application used at different locations for field tests, 1951–54*

Insecticide [1]	Rate of application of net insecticide per acre per application at—		
	Beltsville, Md.	State College, Miss.	New Brunswick, N. J.
	Pounds	*Pounds*	*Pounds*
Aldrin, pure 50 percent W.P.[2]	2.5	-----	-----
Aldrin, technical 50 percent W.P.[3]	2.5	1	1
Dieldrin, 50 percent W.P.	2.5	1	1
Heptachlor, 25 percent W.P.	5.0	4	4
Chlordane, 50 percent W.P.	5.0	4	4
Isodrin, 50 percent W.P.	2.5	1	1
Endrin, 50 percent W.P.	2.5	1	1
Dilan, 48 to 50 percent W.P.	5.0	4	4
BHC, technical W.P.[4]	5.0	1	1
BHC, technical W.P.[5]	-----	1	-----
Lindane, 25 percent W.P.	-----	-----	1
Toxaphene, 40 percent W.P.	5.0	5	5
DDT, 50 percent W.P.	-----	2	1
TDE, 50 percent W.P.	-----	-----	1
Malathion, 25 percent W.P.	-----	-----	4

[1] W.P. indicates wettable powder.
[2] The pure aldrin preparation contained 50 percent pure aldrin.
[3] The technical aldrin preparation contained 50 percent technical aldrin (47.5 percent pure aldrin equivalent and 2.5 percent chlorine-bearing impurities).
[4] Containing 6 percent gamma isomer and 9 percent other isomers.
[5] Containing 12 percent gamma isomer and 18 percent other isomers.

At State College, Miss., a small compressed-air knapsack sprayer was used. Spray mixtures of known concentrations were prepared, each in a constant amount of water, in excess of the amounts required to cover single plots. The required amount of insecticide was delivered by rapidly and repeatedly covering the plot with spray during a predetermined time-interval. Calibration of the sprayer, starting with constant amounts of mixture in the tank and approximately equal pressures for each run, showed that the desired quantity of mixture could be delivered repeatedly with reasonable precision in a measured time-interval. Applications were timed with a stopwatch. To verify the intended applications, the quantity of mixture remaining in the tank after application was measured.

CROP RESPONSES

The primary purpose of this work was to determine possible effects of insecticide residue accumulations in the soil upon plant response. Incidental to affording chances for residues to accumulate, it was obviously necessary to apply the several insecticides to the foliage of crop plants. During this possible buildup period any differences in crop growth associated with treatment might be caused by the immediate and direct effect of the application to the foliage, instead of, or in addition to, any residue that might have accumulated in the soil. This buildup period, however, was not useless as a source of information about residue effects.

The dosages used, although heavy, were intended to be within safe limits insofar as any immediate and direct effects on the plants were known. So little was known, however, about some of the newer substances when the work was started that there was some risk that some immediate and direct effects might occur. If such effects occurred, true residue effects could be determined only by growing nonsprayed crops after a series of sprayed crops. On the other hand, it should be reasonably safe to conclude that in the absence of any effect associated with treatment, no harmful residue effects were present. This consideration is of particular importance regarding some of the treatments at some locations where the frequency of applications and total amounts applied were very high.

RESULTS

PRELIMINARY WORK AT BELTSVILLE, MD.

TESTS IN GREENHOUSE

Duplicated Treatments

In the greenhouse exploratory tests involving only duplicate plots of each treatment, great differences were necessary for statistical significance of differences between treatments within single tests. Single tests rarely showed such differences. Aside from possible direct injury of the spray suspensions to the foliage, no marked differences would be expected to follow the treatments until after many applications had been made.

Table 3 summarizes the accumulative results of repeated sprayings of 16 successive plantings with 10 insecticides over nearly 3 years and the behavior of 4 nonsprayed plantings in soil in which plants had been sprayed earlier, using the 10 insecticides. In the first group of 5 tests involving 15 sprayings at 5 pounds per acre, technical BHC was the only insecticide that appeared to produce markedly different results from all the others. Growth on BHC-sprayed plots was only 37 percent of the nonsprayed controls, while on all other sprayed plots it was about 60 to 70 percent.

TABLE 3.—*Growth responses of crop plants in exploratory tests for accumulating insecticide residues in soils through foliage sprays; greenhouse benches, Beltsville, Md., 1950–53* [1]

Insecticide applied	Early total growth per plot of successive plantings of test plants following accumulative applications shown in percentage of check		
	Test plants sprayed		Test plants not sprayed: Corn, bean, and soybean in 4 tests; accumulative applications of insecticide up to 255 pounds per acre [3]
	Beets, spinach, soybean, snap bean, and sorghum in 5 tests; accumulative applications of insecticide up to 75 pounds per acre	Tomato, squash, corn, wheat, and cotton in 11 tests; accumulative applications of insecticide up to 225 pounds per acre [2]	
	Percent	*Percent*	*Percent*
Aldrin	69	60	95
Dieldrin	69	62	96
Chlordane	74	60	100
Toxaphene	60	47	104
TDE	70	55	115
DDT	62	54	105
Methoxychlor	69	60	76
BHC, technical	37	19	88
Lindane	61	35	94
Ovotran	----------	72	97
Significance of differences.	Between 5- and 1-percent level.	Above 1-percent level.	Below 5-percent level.

[1] See table 5 for persistence of insecticides.
[2] Ovotran applied up to 150 pounds per acre.
[3] Ovotran applied up to 180 pounds per acre.

In the succeeding 11 tests involving an additional total of 30 sprayings at the same rate, technical BHC did even more serious injury to growth than for the first 5 tests, and the effects of lindane appeared almost as serious as those of technical BHC. Growth on Ovotran-treated plots was 72 percent of the controls and that of other treated plots ranged from about 50 to 60 percent of the controls. In the second group of tests the treatments averaged consistently a little more harmful than in the first. This may have been caused in part by the accumulative effects of the insecticides building up in the soil, but the harmful effects could have been the result of a greater sensitivity of test plants in that group. The main purpose of these two series of sprayings was to accumulate a residue of insecticides in the soil to be measured later. The response of the sprayed plants is of secondary interest.

The fourth column of table 3 relates to unsprayed test plants. The average response to treatments in four tests was not significantly different from the nonsprayed controls in soil free from insecticides. Not even the BHC and lindane plots showed any marked difference in the average of four tests. The results in this column suggest that the effects noted in the two sprayed groups were caused largely by direct effects of the heavy spray dosages used in efforts to accumulate residues rapidly.

Table 4 shows the response of unsprayed Stringless Black Valentine bean to the soil of the several sprayed plots after it had been exposed to leaching as described on page 2. This variety is very sensitive to DDT. The accumulations of DDT and of TDE, a related compound, appeared definitely toxic to this bean, as did the accumulations of dieldrin and Ovotran. Although the yields of beans from all treatments were less than the control, yields from some of the treatments were very slightly less, and only four yields were significantly below the control.

The second column of table 5 shows the approximate percentage of the insecticides that was found in the soil of the respective sprayed plots. The four substances that depressed growth of bean significantly (table 4) all showed a more marked tendency to accumulate than did any others, except methoxychlor. This insecticide, another member of the DDT family, has been elsewhere found to be rather highly stable but far less toxic than DDT to plants. (It is also a somewhat less potent insecticide and is less toxic to warm-blooded ani-

TABLE 4.—*Growth response of Stringless Black Valentine bean after accumulative applications of 250 pounds per acre of insecticide; test crop not sprayed; grown in greenhouse bench after leaching of soil to remove inorganic salts, Beltsville, Md., 1954* [1]

Insecticide applied	Weight of plants per plot [2]
	Grams
Aldrin	637
Dieldrin	536*
Chlordane	674
Toxaphene	611
TDE	536*
DDT	521*
Methoxychlor	631
BHC, technical	666
Lindane	648
Ovotran [3]	544*
None	696
Least significant difference at 5-percent level	98

[1] See table 5 for persistence of insecticides.
[2] *=significant at the 5-percent level.
[3] 120 pounds per acre accumulative application.

TABLE 5.—*Accumulation of certain insecticides in soil following foliage application at cumulative quantities shown for exploratory tests in greenhouse and in coldframes, Beltsville, Md., 1949–53*

Insecticide applied	Recovery of organic chlorine [1] in percent of total pounds per acre of material applied in—					
	Greenhouse test; 34 months, 45 sprays, total 225 pounds	Coldframe test [2] after—				
		12 months, 10 sprays, 37.5 pounds	24 months, 20 sprays, 75 pounds	36 months, 31 sprays, 116 pounds	48 months, 33 sprays, 124 pounds	60 months, 33 sprays, 124 pounds
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Aldrin	31	16	10	13	6	6
Dieldrin	68	37	34	37	29	34
Chlordane	35	11	8	12	10	10
DDT	85	54	40	42	32	34
Methoxychlor	89	40	37	37	18	6
TDE	83	35	43	47	36	41
BHC, technical	43	18	12	12	9	8
BHC, alpha	18	18	11	9	7	6
BHC, beta	66	56	52	51	35	35
BHC, gamma	21	18	12	9	6	6
BHC, delta	45	39	34	25	18	18
Lindane	29	11	5	7	6	4
Toxaphene	66	32	34	38	30	29

[1] Determined as organic chlorine and calculated to insecticide equivalent.
[2] See table 6 for test-plant responses.

mals than DDT.) About 70 to 80 percent of the DDT, TDE, dieldrin, and Ovotran applied was found in the soil after 45 heavy sprayings over a period of nearly 3 years. The bean test shown in table 4 was run more than a year after the determinations shown in column 2 of table 5.

Toxaphene here shows about the same tendency to accumulate as does dieldrin and nearly as much as DDT, but pound for pound it appears much less toxic than dieldrin or DDT to most test plants we have tried. Aldrin, technical BHC, and lindane, among the compounds shown in tables 3 and 4, are the least likely to accumulate in the soil in large amounts.

Nonreplicated Treatments

One side bench was used over a 3-year interval for observation on effects of repeated sprayings with technical BHC and the alpha, beta, gamma, and delta isomers of BHC. Accumulative applications reached 150 pounds per acre. Small-grain varieties were highly susceptible to injury in these tests; corn and sorghum somewhat less susceptible. The alpha isomer appeared injurious to oats but not to rye, sorghum, corn, cotton, and beans. The delta isomer appeared most harmful to these test plants; the technical mixture and beta isomer were highly toxic, with gamma isomer moderately toxic.

Nonsprayed corn appeared injured by soil residue only in the delta and beta isomer treatments, but nonsprayed oats was injured by residues of all BHC materials.

Table 5, column 2, shows that of the BHC isomers alpha and gamma tend to accumulate the least, while beta and delta accumulate more rapidly.

TESTS IN COLDFRAMES

In 1949 a series of spray-accumulation tests was established on Chester loam soil in coldframes with 13 substances at 2 levels in each of 2 frames. Here, as in the greenhouse, the main objective was to get some idea of the rates at which the several substances would accumulate in the soil following frequent heavy spray applications. The growth responses of all the sprayed crops were analyzed statistically. Lack of significant differences would indicate no harm from either the direct applications or from such residues as might have accumulated, but differences (when plants were sprayed) could be caused by either one or both conditions.

Table 5 shows the list of 13 substances used. Table 6 summarizes the result of 16 successive test crops grown and also shows the accumulative total amounts of insecticides applied through the growing of each test. Individual spray applications were at the rates of 2.5 and 5.0 pounds per acre. Only 2 true replicates were established for these exploratory tests. With 2 rates of application of each substance, however, considerably more precision was possible than in the greenhouse tests. Table 7 shows the details of results with plants grown in 1954 after treatments had been discontinued.

Table 6 shows that significant differences in growth were noted within only 4 of the 16 test crops grown over 5 years: One crop of beans, 1 crop of radishes, and 1 crop of rye, all of which are highly sensitive to 1 or more of the insecticides used, and 1 crop of turnips. These

TABLE 6.—*Summary of response of crop plants to accumulation of certain insecticides in the soil through foliage applications to successive crops; coldframe tests, Beltsville, Md., 1949–54* [1]

Test plants grown in individual tests, in chronological order	Accumulative amounts of insecticides applied per acre		Yields recorded on—	Response to treatments
	Light rate	Heavy rate		
	Pounds	*Pounds*		
Rye	10	20		
Pea, garden	17½	35	Pods, vines	Differences not significant.
Bean, snap, bush	25	50	Pods	Do.
Do. [2]	25	50	Total tops	Do.
Rye	27½	55	do	Do.
Pea, garden	32½	65	do	Do.
Corn, sweet	37½	75	do	Do.
Bean, snap, bush	42½	85	do	Heavy rate delta BHC significantly toxic. DDT and technical BHC at heavy rate tended to be toxic but not significantly so.
Oats	50	100		
Pea, garden	57½	115	Pods, vines	Differences not significant.
Bean, snap, bush	67½	135	Total tops	Do.
Radish	75	150	Total plants	Delta BHC at both rates and technical BHC at heavy rate greatly depressed yields. Differences significant.
Rye	77½	155	Total tops	Significant differences at heavy rates. Beta, technical, and delta BHC definitely toxic.
Oats [2]	77½	155	do	Differences not significant.
Bean, snap, bush	82½	165	do	Do.
Turnip [2]	82½	165	Tops	DDT, TDE, toxaphene, and BHC depressed growth significantly.
			Roots	Only beta BHC depressed growth significantly.
			Total plants	Only toxaphene depressed growth significantly.
Bean [2]	82½	165	Total plants	Differences not significant.
Do. [2]	82½	165	Pods	DDT plots produced smallest growth. Not significantly below control.
Overall significance of response to treatment.				At light rate of application, significance below 5-percent level; at heavy rate of application, significance above 1-percent level.

[1] See [illegible] 5 for substances applied to foliage and tendency to accumulate in soil.

[2] Not sprayed.

TABLE 7.—*Effects of spray accumulations in soil upon growth of turnips and beans that were not sprayed; coldframes, Beltsville, Md., 1954*

Insecticide prevously applied [1]	Yield per plot of [2]—				
	Turnips		Beans	Beans	
	Roots [3]	Total plants [3]	Total plants [3]	Pods	Total plants
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Aldrin	8. 0	15. 8	6. 0	2. 8	5. 6
Dieldrin	8. 9	17. 1	5. 1	2. 2	4. 7
Chlordane	8. 6	17. 7	6. 0	2. 8	5. 9
Toxaphene	8. 4	15. 0*	6. 0	2. 5	5. 2
DDT, technical	8. 3	15. 7	4. 7*	2. 0	4. 2
TDE	8. 5	16. 0	5. 1	2. 2	4. 6
Methoxychlor	9. 3	18. 1	5. 8	2. 6	5. 7
BHC, technical	8. 1	15. 4	6. 1	2. 9	6. 1
Lindane	8. 7	16. 5	5. 7	2. 8	5. 9
None	8. 6	17. 3	6. 0	2. 8	6. 1
L. S. D. at 5-percent level	(4)	2. 0	1. 2	(4)	(4)
BHC, alpha	9. 1	16. 7	5. 6	2. 8	5. 5
beta	7. 1*	13. 3	5. 6	3. 0	5. 7
gamma	8. 0	14. 6	5. 5	2. 7	5. 1
delta	7. 6	14. 7	5. 7	3. 0	5. 8
None	8. 6	15. 7	5. 4	2. 8	5. 6
L. S. D. at 5-percent level	1. 2	4. 0	(4)	(4)	(4)

[1] Total accumulative application 1950-53 was 82.5 pounds and 165 pounds, respectively, at 2 levels (see table 6).
[2] With no effect of "level" of application, figures in table are means of 2 levels.
[3] *=significant at the 5-percent level.
[4] Not significant.

significant responses all occurred after considerable accumulative amounts of the insecticides had been applied. It is not clear, however, to what extent soil accumulations may have contributed to these results, except with turnip, which was not sprayed. Two crops of beans after treatments ceased failed to show significant harmful effects of treatment (table 7). Only beta, delta, and technical BHC produced significant responses in sprayed crops, although heavy applications of DDT tended to depress yields of beans.

When the results of the 13 tests through the last spraying were combined (table 6), using the interaction treatments × tests as a measure of significance, variances in growth on the plots receiving the light rate of application were below the 5-percent level; variances for the high rate were above the 1-percent level. Most of this effect was the result of direct toxicity of the heavy dosages of technical BHC and the beta and delta isomers of BHC.

The third to seventh columns of table 5 are the means of the percentages of remaining insecticides for the two rates of application. Variance analysis of the entire body of data showed no significant differences in the *percentage* of accumulative applications detected in the soil at the two rates. The *poundage* detected in the high-rate plots was approximately double that in the low-rate plots, but the percentage rates of accumulation were essentially the same for both dosages.

After 33 sprayings over 4 years with accumulative applications of 83 and 165 pounds per acre (mean 124 pounds), percentages ranging from 6 to 7 percent of alpha and gamma BHC, aldrin, and methoxychlor preparations up to about 35 to 40 percent of the TDE were found in the soil. TDE, DDT, beta BHC, and dieldrin accumulated most rapidly of the substances used in this series, with an average of about 35 percent remaining. Toxaphene accumulated nearly as rapidly as the four substances just mentioned. Technical BHC and chlordane appear to be among the less persistent substances, with only about 10 percent remaining in the soil a year after cessation of 4 years' applications. Technical BHC appears more persistent than the alpha and gamma isomers, doubtless because of the relatively persistent beta and delta isomers that it contains as impurities. The results for chlordane are a bit erratic, but it appears to accumulate little more rapidly than aldrin and technical BHC, and much less rapidly than toxaphene and dieldrin.

The seventh column of table 5 shows the residues a year after the 4 years of spraying was terminated. About 40 percent of the TDE; 35 percent of the dieldrin, DDT, and beta BHC; and 30 percent of the toxaphene remained. Only 8 to 10 percent of the technical BHC and chlordane remained, and about 5 percent of the aldrin, alpha and gamma BHC, and methoxychlor.

Table 5 shows that either our techniques were rather rough or the rate of accumulation of these several substances varied considerably from year to year. For unknown reasons, the data for most substances formed relatively flat curves. The figures for the last 2 years, however, suggest more definitely the relative rates of accumulation and disappearance.

Thus, in the long run, it appears that about 75 to 80 percent of the dieldrin, DDT, TDE, beta BHC, and toxaphene used each year tends to reach the soil and persist until the next; 65 to 70 percent of the methoxychlor and delta BHC; and 40 percent or less of aldrin, chlordane, technical BHC, alpha BHC, gamma BHC, and lindane. In fact, only about 10 to 20 percent of these last were recovered in the first 2 years, but the later recoveries suggested a higher rate of accumulation than that.

At 80-percent persistence, the accumulation would level off at about 4 times the annual rate of application in about 20 years. At 70 percent, accumulation will level off at about 2½ times the annual rate in about 15 years; at 40 percent, it will level off at about two-thirds the annual rate in 6 or 7 years; but with only 20-percent persistence, it will level off at about one-quarter the annual application in about 4 years. Under other conditions materially different prospects may appear, as in column 2 of table 5. Figure 1 shows the concentrations that would be present immediately before the next succeeding annual application.

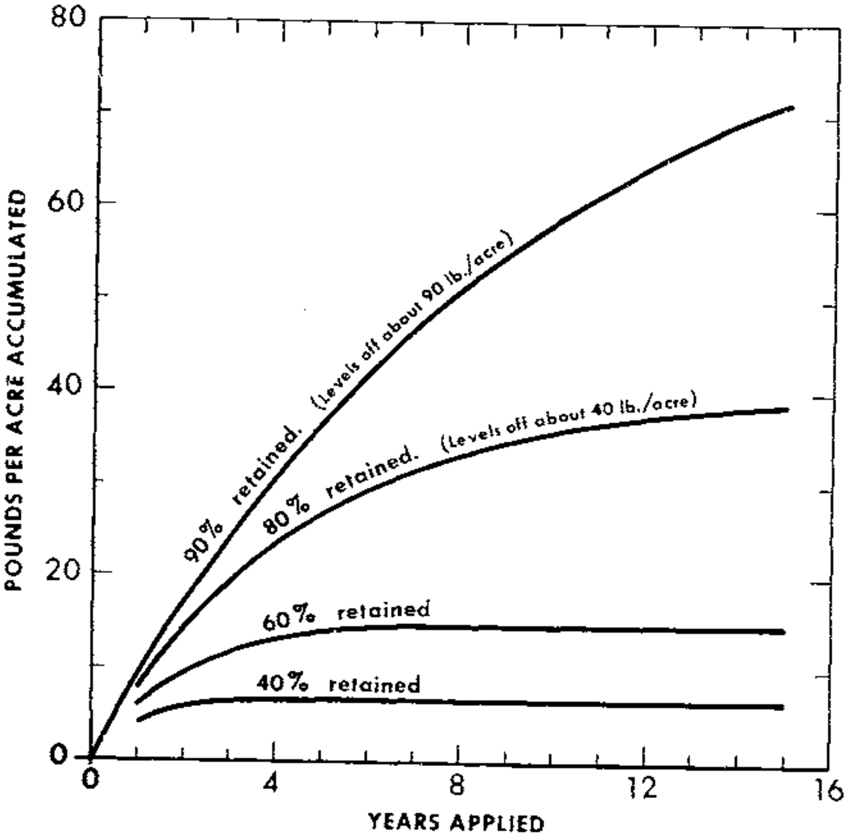

FIGURE 1.—Calculated amounts of insecticide accumulated in soil following applications of 16 pounds per acre per year, assuming 40-, 60-, 80-, and 90-percent persistence annually.

ACCUMULATIONS OF INSECTICIDES IN PLANTS

Determinations of organic chlorine were made in samples from one crop each of turnips and beans grown in 1954 on these exploratory plots at Beltsville. Turnips showed no organic chlorine within limits of error of the method. Snap beans showed none from the plots treated with aldrin, methoxychlor, or lindane. Less than 0.1 p. p. m. was found in those from the toxaphene treatments, 0.2 p. p. m. from the TDE treatments, and 0.3 p. p. m. from the heavy dieldrin treatments. In beans from the light treatments with chlordane, 0.5 p. p. m. of organic chlorine was found, but none in those from the heavy-treated plots, thus raising some question about the validity of the figure just given.

A few samples of garden peas from the plots receiving different isomers of BHC were analyzed for the respective isomers. Amounts of 0.1 to 0.2 p. p. m. were found.

TASTE EVALUATIONS

Turnips from the coldframes in 1954 (see tables 3 and 4) were rated for quality. Roots from control plots scored 4.6 out of a possible score of 5. Turnips from plots treated with various indicated substances scored as follows: Purified gamma BHC, 2.9; commercial lindane, 2.4; technical BHC, 1.7. All roots from these treated plots showed significant off-flavor and low acceptability.

COOPERATIVE EXPERIMENTS, BELTSVILLE, MD.

CROP RESPONSES

Since the 6- by 6-foot plots established in quadruplicate in 1951 yielded relatively precise and significant crop data, the results are presented in detail. The first five test crops grown were all heavily sprayed with insecticides, and the sixth crop was not sprayed. Table 8 shows that significant differences occurred among treatments in each crop except peas.

It appears that oats was somewhat sensitive to all the substances used, especially to heptachlor, BHC, and toxaphene. Spinach grown on the same plots was very highly sensitive to BHC. Toxaphene, heptachlor, and Dilan also depressed growth of spinach significantly.

Yields of pods of garden pea, grown as the second crop, were not affected significantly. Yields of total tops of peas when no spray was applied differed significantly from the control. The yield of the BHC plots, however, was significantly below the yield of some of the other treatments that were slightly above the control.

In the third crop, snap beans, yields of neither pods nor total tops of any treatment were significantly below the control. The BHC treatment, however, gave the lowest yield of pods and chlordane and BHC the lowest yields of total tops. Yields from several treatments were significantly lower than the highest observed in this crop.

Radish was significantly injured by every treatment, and especially so by BHC, Dilan, toxaphene, and heptachlor. This was true for both roots and total plants.

The fifth crop grown, rye, was very seriously injured by BHC and also significantly injured by Dilan, chlordane, and heptachlor in descending order of severity.

Aldrin, dieldrin, isodrin, and endrin were intermediate in effect on those crops susceptible to all treatments by spraying.

Heavy sprays of BHC tend to produce some direct injury to foliage of sensitive crops, but the plants usually outgrow it.

The sixth crop, carrot, was grown without spraying in order to determine effects of soil accumulations of insecticides free of any effects of foliage applications. Uniform stands and growth within treatments resulted in unusually low errors. As in the sprayed crops, technical BHC plots yielded the least, significantly below the controls. Pure aldrin, endrin, heptachlor, and toxaphene residues slightly and significantly depressed root yields. Technical aldrin, heptachlor, chlordane, endrin, and toxaphene slightly depressed yields of total plants significantly but not the root yields. Thus, the accumulative harmful effect of residues of most of these substances on growth of carrot is measurable.

Following an autumn cover crop of Abruzzi rye that was inadvertently given a double treatment and then turned under in January, a second crop of spring carrots was grown in 1954.

TABLE 8.—*Accumulative applications of certain insecticides and their effects on growth of oats, spinach, peas, snap beans, radish, rye, and carrot, outdoor frames, Beltsville, Md., 1951–54*

Insecticide applied	Accumulative total insecticide applied per acre to foliage and yield per plot of crop shown [1]								
	First crop			Second crop, pea			Third crop, bean		
	Total insecticide	Yield of— Oats tops	Yield of— Spinach tops	Total insecticide	Yield of— Pods	Yield of— Total tops	Total insecticide	Yield of— Pods	Yield of— Total tops
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Aldrin, pure	10	9. 9*	3. 5	20	5. 4	30. 2	30	6. 8	19. 2
Aldrin, technical	10	10. 1*	3. 9	20	4. 1	26. 9	30	7. 0	19. 2
Dieldrin	10	9. 8*	3. 8	20	5. 5	28. 9	30	7. 1	20. 6
Heptachlor	20	9. 1*	3. 0*	40	5. 4	29. 5	60	6. 8	19. 6
Chlordane	20	11. 5*	3. 4	40	5. 0	31. 4	60	6. 8	18. 3
Isodrin	10	10. 1*	4. 6	20	5. 5	29. 7	30	8. 4*	22. 9
Endrin	10	9. 9*	4. 5	20	5. 1	30. 4	30	8. 7*	22. 7
Dilan	20	10. 1*	3. 3*	40	6. 4	31. 8	60	7. 6	20. 6
BHC, technical	20	9. 5*	. 5*	40	5. 0	25. 8	60	6. 4	18. 7
Toxaphene	20	8. 9*	2. 1*	40	5. 8	30. 0	60	7. 5	20. 4
None		12. 7	4. 1		4. 9	29. 6		6. 9	20. 2
L. S. D. at 5-percent level		1. 0	0. 8					1. 4	

See footnotes at end of table.

TABLE 8.—*Accumulative applications of certain insecticides and their effects on growth of oats, spinach, peas, snap beans, radish, rye, and carrot, outdoor frames, Beltsville, Md., 1951–54*—Continued

Insecticide applied	Accumulative total insecticide applied per acre to foliage and yield per plot of crop shown							
	Fourth crop, radish			Fifth crop, rye		Sixth crop, carrot[2]		
	Total insecticide	Yield of— Roots	Yield of— Total plants	Total insecticide	Yield of tops	Total insecticide	Yield of— Roots	Yield of— Total plants
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Aldrin, pure	40	7. 2*	12. 0*	45	9. 0	45	15. 9*	36. 6
Aldrin, technical	40	7. 3*	11. 8*	45	8. 5	45	16. 3	32. 6*
Dieldrin	40	7. 1*	11. 7*	45	8. 8	45	16. 3	38. 6
Heptachlor	80	3. 4*	6. 2*	90	7. 2*	90	15. 9*	33. 5*
Chlordane	80	5. 5*	8. 1*	90	7. 1*	90	16. 6	32. 0*
Isodrin	40	7. 5*	11. 4*	45	7. 9	45	16. 8	36. 0
Endrin	40	6. 7*	11. 3*	45	8. 0	45	15. 9*	33. 8*
Dilan	80	1. 9*	3. 3*	90	5. 5*	90	18. 1	36. 3
BHC, technical	80	. 3*	. 7*	90	1. 6*	90	14. 6*	37. 7
Toxaphene	80	2. 5*	5. 0*	90	7. 7	90	15. 4	31. 2*
None	----------	9. 5	14. 5	----------	9. 3	----------	17. 7	39. 7
L. S. D. at 5-percent level	----------	1. 2	1. 2	----------	1. 8	----------	1. 7	5. 9

Insecticide applied	Total insecticide	Eighth crop, carrot [2] [3]		Ninth crop, beans [2]	
		Yield of—		Yield of—	
		Roots	Total plants	Pods	Total plants
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Aldrin, pure	65	24. 6	41. 9	6. 9*	13. 2*
Aldrin, technical	65	26. 2	42. 4	8. 3	15. 9
Dieldrin	65	24. 5	42. 7	7. 1*	13. 6*
Heptachlor	130	23. 5	39. 2	6. 9*	13. 7*
Chlordane	130	24. 9	39. 3	8. 7	16. 6
Isodrin	65	25. 6	43. 0	7. 3*	14. 1*
Endrin	65	23. 3	40. 1	7. 4*	14. 0*
Dilan	130	25. 4	41. 0	7. 4*	13. 9*
BHC, technical	130	21. 2*	36. 8*	5. 6*	10. 5*
Toxaphene	130	22. 1*	37. 7*	7. 6	14. 9
None		25. 7	45. 1	8. 5	16. 2
L. S. D. at 5-percent level		2. 8	7. 1	1. 1	2. 0

[1] *=significant at the 5-percent level.
[2] No insecticides applied to this crop.
[3] Seventh crop was rye, sprayed double the usual quantity of insecticide, and turned under in January.

Comparison of the two crops of carrots (table 8) shows that several of the insecticide residues that significantly decreased yields of roots or total plants of the first crop did not significantly reduce such yields in the second crop. Yields of roots and total plants were reduced in the latter crop only by technical BHC and by toxaphene. Heptachlor and chlordane, used at the same rates as technical BHC and toxaphene, appeared again to depress yields somewhat but not significantly.

The greatest depressions in yield were less than 20 percent below the controls but were significant by virtue of a nice degree of precision; the least significant differences for both crops of carrot roots were approximately 10 percent of the control plots.

ACCUMULATIONS OF INSECTICIDES IN SOIL

Table 9 shows the percentages of the several insecticides found in the soil 1, 2, and 3 years after starting treatments, together with accumulative amounts of each applied before each sampling. Soil samples were taken each autumn.

For reasons not clear, the amounts of endrin detected are in some doubt; they are surprisingly high, 100-percent recovery of the compound in the first 2 years. Although possibly in error, these values suggest very high stability and tendency of endrin to accumulate.

Dieldrin, Dilan, and toxaphene are next most persistent, showing about 50-percent recovery after 3 years. Isodrin and heptachlor also seem rather highly persistent, with about 35 percent remaining. BHC, as in other instances, clearly accumulated the least, with about 5 percent remaining. Aldrin and chlordane are intermediate, with about 18 percent showing up after 3 years.

TABLE 9.—*Insecticides remaining in soil after foliage applications to successive crops in outdoor frames, Beltsville, Md., 1951–54*

Insecticide applied	Recovery of organic chlorine from soil [1] in percentage of total pounds applied per acre of material in—					
	1 year		2 years		3 years	
	Total applied	Amount remaining [2]	Total applied	Amount remaining [2]	Total applied	Amount remaining [2]
	Pounds	*Percent*	*Pounds*	*Percent*	*Pounds*	*Percent*
Aldrin, pure	40	32	45	17	65	17
Aldrin, technical	40	46	45	29	65	19
Dieldrin	40	72	45	69	65	47
Isodrin	40	46	45	59	65	33
Endrin	40	100	45	100	65	78
Chlordane	80	16	90	20	130	17
Heptachlor	80	23	90	33	130	38
BHC, technical	80	7	90	5	130	5
Toxaphene	80	50	90	66	130	53
Dilan	80	46	90	40	130	48

[1] Calculated as representing mixture in the surface 6 inches, the depth to which the beds were thoroughly worked.
[2] Percentage of amount applied.

A smooth curve of the residues accumulated cannot be expected for any substance because of the irregular applications. The excessive dosages in the autumn of 1953 could upset a smooth trend.

ACCUMULATIONS OF INSECTICIDES IN PLANTS

Snap Beans

In the summer of 1952 Stringless Black Valentine beans were grown on the plots set up in 1951 (see third crop in table 8) and sprayed four times as were preceding crops. After the third spraying bean pods were harvested from certain rows of two replicates for organic chlorine determinations. There was the possibility of direct absorption of some of the chemicals as applied to that crop during its growth as well as uptake of such chemicals or their decomposition products from the soil.

Upon analysis, the beans from the toxaphene plot showed 0.6 p. p. m. organic chlorine. Beans from plots treated with aldrin, dieldrin, isodrin, endrin, chlordane, heptachlor, and Dilan showed no significant difference from those of the control plots. Beans from the BHC plots were not analyzed.

Entire pods from the same plots were subjected to bioassay by E. P. Lang of the Food and Drug Administration. House flies were exposed to petroleum ether extract residues. No insecticide was detected in extracts of pods from plots treated with chlordane, heptachlor, toxaphene, or aldrin. Results from other treatments were: Endrin, 0.13 p. p. m.; BHC, 0.10 p. p. m.; dieldrin, 0.08 p. p. m.; isodrin, 0.04 p. p. m. The amounts found could well have been residues on the surface following recent spraying.

Garden Peas

Similar bioassay was made of shelled peas from a crop sprayed 4 times following preceding crops that had received 4 sprays (see second crop in table 8). Samples from all treatments except BHC and Dilan were analyzed and all results were negative. According to the methods used, the undetected insecticides could not have been present in amounts greater than 0.02 p. p. m. of aldrin, dieldrin, or heptachlor; 0.06 p. p. m. of isodrin, 0.6 p. p. m. of chlordane or toxaphene; and 0.12 p. p. m. of endrin.

Carrots

Table 10 shows the apparent insecticide content of carrot roots and bean pods in 2 successive years, together with the amounts of insecticide applied to preceding crops. The values are calculated from total organic chlorine found in excess of that in carrots from untreated plots. It is not clear why the equivalent amounts of organic chlorine found in the roots were generally much lower in 1954 than in 1953. although the concentrations of organic chlorine in the soil were about the same in both years. (See possible explanation on p. 4.)

Samples of carrot were also analyzed in 1954 for aldrin by the phenyl azide-photometric method, for dieldrin by the reduction-phenyl azide-photometric method, and for isodrin and dieldrin by a film-exposure bioassay method employing pomace flies. By these methods less than 0.1 p. p. m. of technical aldrin was found, 1.7 p. p. .m. of dieldrin, 0.7 p. p. m. of isodrin, and 3.0 p. p. m. of endrin. The values were very close to those shown in table 10.

TABLE 10.—*Apparent insecticide content of soil and of carrots and beans following repeated heavy spraying of preceding crops with insecticides, in open frames, Beltsville, Md., 1951–54*

Insecticide applied to preceding crops, 1951–53	1953			1954			
	Amount applied[1]	Recovered		Amount applied[1]	Recovered		
		In soil	In carrots		In soil	In carrots	In beans
	P. p. m.	*P. p. m.*	*P. p. m.*	*P. p. m.*	*P. p. m.*	*P. p. m.*	*P. p. m.*
Aldrin, pure	15	2.5	1.3	21.7	3.6	0.6	------
Aldrin, technical	15	4.3	.7	21.7	4.1	.15	0
Dieldrin	15	10.3	10.8	21.7	10.1	2.3	0
Isodrin	15	8.8	1.3	21.7	7.1	.3	0
Endrin	15	15.8	4.0	21.7	16.9	3.0	0
Chlordane	30	6.0	4.1	43.4	7.5	.8	0
Heptachlor	30	10.0	4.0	43.4	16.5	5.2	.4
BHC, technical	[2] 82	4.3	14.9	[2] 119.2	5.8	14.2	0
Toxaphene	30	19.9	6.2	43.4	23.0	.6	0
Dilan	30	12.1	5.6	43.4	20.9	2.1	0

[1] Accumulative total equivalent in parts per million of surface 9 inches of soil.
[2] Total isomers applied in technical BHC.

In observing the effects of the applications of insecticides to preceding crops upon the calculated content in the carrot roots two points must be kept in mind: (1) The dosages were applied at exaggerated rates to obtain rapid accumulation of residues; and (2) the apparent content of insecticide of both soils and carrots is calculated from the analytical figures for organic chlorine, not the specific insecticides determined as such, unless so specified.

Aldrin and isodrin stand out as apparently contributing to very little uptake of chlorinated substances by the carrots. Applications of all other insecticides, however, appear to result in relatively large amounts being absorbed. BHC is noteworthy because it resulted in a concentration of organic chlorine in the roots far greater than that in the soil. The plant seems to have an affinity for BHC or some of its decomposition products.

TASTE EVALUATIONS

It has been observed elsewhere[5] that the flavor of produce of many plants is readily contaminated by BHC in the soil, even the flavor of fruits and seeds that develop well above the soil surface. The adverse effect of BHC on quality of root crops is well known. The United States Department of Agriculture does not recommend the use of BHC on any vegetable crop.

[5] BOSWELL, V. R., CLORE, W. J., PEPPER, B. B., and others. EFFECTS OF CERTAIN INSECTICIDES IN SOIL UPON CROP PLANTS. U. S. Dept. Agr. Tech. Bul. 1121, 59 pp., illus. 1955.

Table 11 shows that only the samples of carrots and beans from the BHC-treated plots were rated significantly different from the controls or from other treatments. Both flavor and general acceptability of those samples were very poor. In 1953 a marked degree of bitterness was noted in carrots from the control plots and the treated plots except those receiving BHC. In the BHC lots bitterness may have been masked by the musty flavor of BHC. Sixty percent of the judges noted bitterness in the controls. Bitterness was detected in samples from treated plots (except BHC), ranging from 65 percent of the judgments for dieldrin down to 35 percent and 40 percent for purified and technical aldrin, respectively. It is possible that this generally occurring bitterness and only fair to poor quality in the crop as a whole may have masked minor differences associated with treatment.

In addition to the general bitterness, which was probably not related to treatment, a variety of other undesirable flavors was described in judgments of samples from all treatments except those involving technical BHC. Judgments of any one described off-flavor were too few

TABLE 11.—*Effect of soil residues of certain insecticides on flavor and general acceptability of carrots and beans, outdoor frames, Beltsville, Md., 1953–54*

Insecticide used on preceding crops	Mean score for flavor and acceptability of crop in year shown [1]					
	Flavor [2]			General acceptability [3]		
	1953	1954		1953	1954	
	Carrot	Carrot	Bean	Carrot	Carrot	Bean
Aldrin, technical	2.6	------	4.4	2.0	------	3.9
Dieldrin	2.8	------	4.6	2.3	------	4.1
Isodrin	2.4	4.9	------	1.9	3.5	------
Endrin	2.8	------	------	2.4	------	------
Chlordane	3.0	------	4.0	2.4	------	4.4
Heptachlor	2.6	------	------	2.0	------	------
Methoxychlor	------	------	4.6	------	------	4.1
TDE	------	------	4.3	------	------	3.7
DDT	------	------	4.2	------	------	3.8
BHC, technical	1.0*	1.1*	2.3*	1.0*	1.1*	2.1*
Lindane	------	------	3.6*	------	------	3.0*
Toxaphene	2.8	------	4.6	2.1	------	3.9
Dilan	2.5	4.9	------	2.2	3.6	------
None	3.1	4.9	4.6	2.5	3.7	4.3
L. S. D. at 5-percent level	0.9	0.9	1.0	0.7	0.8	0.9

[1] * = significant at 5-percent level.
[2] 5 indicates no off-flavor; 4, perceptible off-flavor; 3, slightly strong; 2, moderately strong; 1, very strong off-flavor.
[3] 5 indicates very good; 4, good; 3, fair; 2, poor; 1, very poor general acceptability.

and inconsistent to be statistically significant except those of BHC, where an earthy or musty flavor was reported in 90 percent of the judgments. Similar flavors were reported in only 1 to 25 percent of all other judgments, and a green or raw taste in 10 to 30 percent of the judgments.

COOPERATIVE EXPERIMENTS, STATE COLLEGE, MISS.

CROP RESPONSES

Insecticide applications to the first crop (1951) grown at State College, Miss., were all light except in the instance of the 12 percent BHC. Through inadvertence, 17 pounds of gamma BHC per acre was applied instead of 5 pounds. To avoid getting the accumulation on this treatment further out of line with its companion at 6 percent, the next 3 applications were omitted. After the first crop the applications of heptachlor, chlordane, Dilan, toxaphene, and DDT per crop were increased, as shown by the differences between columns 2 and 4 in table 12.

Of the treatments shown in table 12 none produced any significant effects on yield of the first crops of snap beans and of turnips, respectively. In the third crop, Southern peas (*Vigna sinensis*), there were no significant effects on pod yield, but the weights of plants without pods were reduced by chlordane, isodrin, BHC, and DDT. The total plant weights were significantly reduced by all treatments except by toxaphene and dieldrin. It is not clear why the effects were so severe on peas, since the same treatments on the same species the following year did not reduce total plant weights in any instance. In this latter crop, however (the fifth grown and sprayed), dieldrin, chlordane, and endrin significantly depressed yields of pods. Turnip yields were not affected in any of 3 years they were grown despite the considerable total applications of some of the insecticides. The yields of sweetpotatoes were not significantly affected, although yields of the BHC plots receiving large amounts of other isomers in addition to gamma isomer were noticeably lower than the check or other treated plots.

In the first crop of snap beans DDT sprays slightly injured the very young pods in all replicates. Chlordane produced moderate injury in two replicates, and isodrin and endrin produced slight injury in one replicate each. No noticeable direct spray injury occurred later.

ACCUMULATIONS OF INSECTICIDES IN SOIL

The percentages of the several insecticides remaining in the soil at this southern location after 2 years of spray applications were strikingly less than those at Beltsville. The State College values (table 13) average only about half to a third as great as those at Beltsville for roughly comparable periods of sampling.

After 2 years, apparently only negligible quantities of the BHC reached the soil and remained. About 25 percent of the endrin, toxaphene, and DDT remained, and 10 to 12 percent of the other substances.

TABLE 12.—*Accumulative applications of certain insecticides to foliage and their residual effects on growth of turnips, snap beans, and Southern peas, State College, Miss., 1951–54*

Insecticide	Accumulative total insecticide applied per acre to foliage and yield per plot for crop and years shown											
	1951: Snap beans [1]		1952									
			Turnips [1]		Southern peas [1]				Snap beans [1]			
	Total insecticide	Yield [2] per plot	Total insecticide	Yield [3] per plot	Total insecticide	Yield per plot			Total insecticide	Yield per plot		
						Pods	Plants	Total		Pods	Plants	Total
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Aldrin	5	18. 8	10	51	15	2. 9	16. 2	19. 1*	20	3. 8	3. 4	7. 2
Dieldrin	5	18. 3	10	44	15	3. 8	18. 1	21. 9	20	3. 3	2. 8	6. 1
Isodrin	5	16. 9	10	47	15	2. 9	14. 6*	17. 5*	20	3. 0	3. 1	6. 1
Endrin	5	15. 2	10	47	15	2. 9	16. 2	19. 1*	20	2. 6	2. 7	5. 3
Chlordane	5	14. 4	25	38	45	3. 1	14. 5*	17. 6*	65	2. 7	3. 0	5. 7
Heptachlor	5	16. 5	25	49	45	3. 3	16. 2	19. 5*	65	3. 2	2. 9	6. 1
BHC, technical 6 percent [4]	6	17. 1	11	58	16	3. 5	15. 6*	19. 1*	21	2. 2	2. 7	4. 9
BHC, technical 12 percent [4]	17	13. 4	[5] 17	43	[5] 17	3. 5	18. 7	22. 2	[5] 17	1. 7*	3. 8	5. 5
Toxaphene	6	16. 7	31	40	56	3. 3	17. 6	20. 9	76	2. 3	3. 0	5. 3
Dilan	5	17. 1	25	56	45	3. 2	16. 3	19. 5*	65	2. 7	3. 2	5. 9
DDT	5	18. 7	15	53	25	3. 0	15. 9*	18. 9*	35	3. 1	2. 7	5. 8
None	-------	19. 0	-------	52	-------	3. 5	20. 3	23. 8	-------	3. 3	3. 0	6. 3
L. S. D. at 5-percent level	-------	-------	-------	-------	-------	-------	4. 2	3. 7	-------	1. 4	1. 2	2. 0

See footnotes at end of table.

TABLE 12.—*Accumulative applications of certain insecticides to foliage and their residual effects on growth of turnips, snap beans, and Southern peas, State College, Miss., 1951–54*—Continued

Insecticide	Accumulative total insecticide applied per acre to foliage and yield per plot for crop and years shown							
	1953						1954: Sweetpotatoes [5] [6]	
	Turnips [1]		Southern peas [1]					
	Total insecticide	Yield [2] per plot	Total insecticide	Yield per plot			Total insecticide	Yield per plot [2]
				Pods	Plants	Total		
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Aldrin	25	40	30	7.4	14.3	21.7	35	25.9
Dieldrin	25	38	30	6.6*	13.3	19.9	35	28.5
Isodrin	25	43	30	6.9	13.2	20.1	35	23.9
Endrin	25	39	30	5.9*	12.5	18.4	35	27.0
Chlordane	85	37	105	5.6*	12.7	18.3	125	24.7
Heptachlor	85	42	105	7.1	13.2	20.3	125	29.5
BHC, technical 6 percent [4]	26	45	31	6.8	12.5	19.3	36	27.0
BHC, technical 12 percent [4]	22	43	27	7.9	16.0	23.9	32	16.6
Toxaphene	101	38	126	6.8	15.0	21.8	151	29.0
Dilan	85	48	105	7.4	14.6	22.0	125	25.0
DDT	45	39	55	7.8	13.7	21.5	65	23.3
None	----------	41	----------	8.5	15.6	24.1	----------	28.5
L. S. D. at 5-percent level	----------	----------	----------	1.9	----------	----------	----------	----------

[1] Sprayed. *=Significant at 5-percent level. [2] Entire plants. [3] Tops of foliage turnip.
[4] The 6 percent BHC contained 44 percent isomers other than gamma and the 12 percent BHC contained 18 percent other isomers.
[5] Not sprayed. [6] A preceding crop of beans, not harvested, was sprayed.

TABLE 13.—*Accumulation of insecticides in soil following foliage application at accelerated rates, State College, Miss., 1951–53*

Insecticide applied	Recovery of organic chlorine from soil, in percentage of total pounds per acre of material applied, in—			
	1952		1953	
	Total applied	Amount remaining	Total applied	Amount remaining
	Pounds	*Percent*	*Pounds*	*Percent*
Aldrin	20	15	35	11
Dieldrin	20	45	35	14
Isodrin	20	30	35	11
Endrin	20	45	35	25
Chordane	65	18	125	8
Heptachlor	65	23	125	12
BHC, technical 6 percent [1]	168	17	248	5
BHC, technical 12 percent [2]	43	[3] 3	80	3
Toxaphene	76	41	151	24
Dilan	65	23	125	9
DDT	35	49	65	25

[1] Applied as 6 percent gamma and 44 percent other isomers.
[2] Applied as 12 percent gamma and 18 percent other isomers.
[3] None applied since original excessive application.

ACCUMULATIONS OF INSECTICIDES IN PLANTS

Turnips

Turnips from the plots at State College were analyzed for aldrin, dieldrin, isodrin, and endrin. None was found within the limits of error of the methods used, agreeing with the results on turnips at Beltsville. Organic chlorine determinations revealed less than 0.1 p. p. m. of insecticide equivalent as total organic chlorine in turnips from plots that had received Dilan and the high-gamma BHC; 0.9 p. p. m. in those from low-gamma BHC and chlordane treatments; 1.0 and 1.1 p. p. m. from toxaphene and heptachlor plots, respectively; and 2.6 p. p. m. of organic chlorine from DDT plots. Turnips from these treatments were not analyzed for the specific insecticides previously applied, so it is not known how much, if any, of those substances were present in the plant tissues.

Sweetpotatoes

Total organic chlorine was determined also in the marketable sweetpotatoes produced in 1954 and calculated to equivalents of the specific insecticides used. Less than 0.1 p. p. m. was found in roots from the aldrin and isodrin plots, only 0.6 p. p. m. in those from the high-gamma BHC plots, and 1.5 p. p. m. in roots from the Dilan-treated areas.

Roots from all other treatments contained relatively high equivalents of the several insecticides determined as organic chlorine. The results in parts per million of organic chlorine from the remaining treatments were: Dieldrin, 4.3; endrin, 7.3; heptachlor, 7.5; toxaphene, 11.6; DDT, 15.6; and chlordane, 29.6. Some of these values appear excessively high in view of the low recoveries of organic chlorine from the soil. They do indicate, however, the very real possibility that sweetpotatoes may absorb undesirable quantities of some of these chlorinated hydrocarbons or their decomposition products.

TASTE EVALUATIONS

Taste tests of a simple empirical nature were conducted on baked sweetpotatoes from the several treatments at State College. No definite off-flavors or off-odors were consistently detected, although at one tasting session the roots from the BHC plots had a slight off-flavor. At a second session no differences were noted. Finding roots that were definitely off-flavored from the plots treated with low-gamma BHC would not have been surprising, in view of past experience elsewhere.

COOPERATIVE EXPERIMENTS, NEW BRUNSWICK, N. J.

CROP RESPONSES

Table 14 shows the response of Stringless Black Valentine beans to frequent and continued spraying with 13 insecticides and to any residues thereof in the soil. In addition to the basic list of substances (see p. 6), lindane, DDT, TDE, and malathion were included. The applications of aldrin, dieldrin, isodrin, endrin, BHC, lindane, DDT, and TDE were at 1 pound per acre per application, much lighter than those substances were applied at Beltsville (see table 2). Heptachlor, chlordane, Dilan, and malathion were applied at 4 pounds and toxaphene at 5 pounds, a little heavier than the rate at Beltsville. Neither immediate nor accumulative effects of the lighter applications would be expected to be as marked as at Beltsville.

In the first, second, and fourth crops, plots variously treated with endrin, toxaphene, Dilan, and malathion produced significantly greater yields of pods or plants (after removal of pods) 1 or 2 times than did the controls. Since there was no consistent pattern to these superiorities it is not clear whether or not they were merely fortuitous. Pod yields were not significantly increased.

In the first two crops no insecticide treatment significantly depressed yield of either pods or plants, but in both the third and fourth crops technical BHC significantly depressed yields of plants with pods. In one year this difference was caused mainly by lower yield of pods, in the other years by lower yields of plants minus pods. Lindane depressed pod yield in the third year. Again in the fifth crop (table 15) technical BHC significantly lowered yields of plants plus pods and also pods and plants separately. Thus, it appears that the accumulating residue plus direct application of technical BHC was producing progressively more harmful effects.

In the nonsprayed crop of beans the residues of BHC, DDT, and TDE in the soil tended to decrease yields of pods and weights of plants but only the differences due to BHC were significant.

There was no marked tendency for the residues to impair yields of carrot roots. Top growth was depressed slightly by chlordane, isodrin, and malathion, but not significantly. Total weight of carrot plants was not significantly affected.

Yields of turnip roots were lower on the check plots than on any of the treated plots, and top growth also was less on the checks than on any treated plots except those treated with malathion. These yields of the checks were significantly below those of most treated plots. It is possible that an obscure insect infestation occurred in the untreated soil and not in the treated soil, resulting in these differences.

ACCUMULATIONS OF INSECTICIDES IN SOIL

Table 16 shows the accumulative total amounts of the several insecticides applied to the foliage of 5 successive crops of beans for developing residues in the soil. It also shows the percentage of the total chlorinated hydrocarbons applied that was recovered in the autumn of 1954 by analysis for total organic chlorine.

The relative persistence of the several insecticides or their chlorine-bearing decomposition products is seen to be in general agreement with results elsewhere in this work. Only about 5 to 10 percent of the BHC and lindane remained, 20 percent of the aldrin, isodrin, chlordane and heptachlor; 30 to 35 percent of the Dilan, endrin, and dieldrin; and 45 percent of the toxaphene, DDT, and TDE.

TABLE 14.—*Accumulative applications of certain insecticides to foliage and their effects on growth of Stringless Black Valentine bean, New Brunswick, N. J., 1952–53*

Insecticide	1952							
	Accumulative total insecticide applied per acre to foliage and yield per plot for crop shown [1]							
	Spring crop				Fall crop			
	Total insecticide	Yield per plot			Total insecticide	Yield per plot		
		Pods	Plants	Total		Pods	Plants	Total
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Aldrin	5	5. 4	5. 4	10. 8	12	8. 6	8. 3	16. 9
Dieldrin	5	5. 6	6. 7	12. 3	12	6. 5	7. 5	14. 0
Isodrin	5	6. 0	6. 4	12. 4	12	8. 3	8. 4	16. 7
Endrin	5	6. 9	8. 4*	15. 3*	12	7. 7	7. 8	15. 5
Chlordane	20	6. 2	6. 8	13. 0	48	6. 7	7. 5	14. 2
Heptachlor	20	6. 1	7. 0	13. 1	48	7. 5	7. 5	15. 0
BHC, technical	5	4. 9	5. 3	10. 2	12	7. 5	8. 0	15. 5
Lindane	5	6. 2	6. 5	12. 7	12	8. 1	7. 6	15. 7
Toxaphene	25	6. 9	8. 0*	14. 9*	60	8. 7	9. 0*	17. 7*
Dilan	20	6. 4	6. 7	13. 1	48	8. 1	7. 3	15. 4
DDT	5	7. 1	7. 2	14. 3	12	8. 1	8. 1	16. 2
TDE	5	6. 1	5. 6	11. 7	12	7. 6	7. 7	15. 3
Malathion	20	6. 6	7. 5*	14. 1	48	6. 5	6. 3	12. 8
None		5. 6	5. 7	11. 3		7. 6	7. 2	14. 8
L. S. D. at 5-percent level [2]			1. 9	4. 0			1. 9	3. 4
L. S. D. at 5-percent level [3]			1. 6	3. 5			1. 6	2. 9

	1953							
Aldrin	19	4.6	9.8	14.4	24	8.0	7.8	15.8
Dieldrin	19	4.5	9.5	14.0	24	8.4	6.9	15.3
Isodrin	19	5.6	8.2	13.8	24	7.8	7.5	15.3
Endrin	19	6.1	8.7	14.8	24	7.7	6.9	14.6
Chlordane	76	5.4	7.8	13.2	96	7.9	7.0	14.9
Heptachlor	76	4.7	7.6	12.3	96	6.9	6.5	13.4
BHC, technical	19	4.4	6.0*	10.4*	24	5.5*	6.3	11.8*
Lindane	19	5.0	6.6*	11.6	24	7.7	7.3	15.0
Toxaphene	95	6.3	9.5	15.8	120	7.6	7.5	15.1
Dilan	76	5.6	7.9	13.5	96	7.4	10.4*	17.8*
DDT	19	4.5	8.9	13.4	24	7.7	8.6*	16.3
TDE	19	6.4	9.1	15.5	24	7.3	8.8*	16.1
Malathion	76	5.3	8.8	14.1	96	8.5	8.6*	17.1*
None	----------	5.5	9.1	14.6	----------	7.6	6.8	14.4
L. S. D. at 5-percent level [2]	----------	----------	2.5	4.6	----------	1.5	2.0	2.4
L. S. D. at 5-percent level [3]	----------	----------	2.2	4.0	----------	1.3	1.7	2.1

[1] *=significant at 5-percent level.
[2] For comparisons among treatments.
[3] For comparisons between treatment versus no treatment.

TABLE 15.—*Accumulative applications of certain insecticides to foliage and their residual effects on growth of Stringless Black Valentine snap bean, Chantenay carrot, and Purple Top White Globe turnip, New Brunswick, N. J., 1952–54*

Insecticide	1954						
	Accumulative total insecticide applied per acre to foliage and yield per plot for crop shown [1]						
	Total insecticides	Beans [2]			Beans [3]		
		Pods	Plants	Total	Pods	Plants	Total
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Aldrin	30	5. 6	5. 0	10. 6	2. 6	2. 6	5. 2
Dieldrin	30	5. 1	4. 2	9. 3	2. 9	2. 7	5. 6
Isodrin	30	6. 1	4. 8	10. 9	2. 7	2. 7	5. 4
Endrin	30	6. 0	4. 6	10. 6	2. 5	2. 6	5. 1
Chlordane	120	6. 4	4. 6	11. 0	2. 9	2. 8	5. 7
Heptachlor	120	4. 8	3. 8	8. 6	2. 6	2. 8	5. 4
BHC, technical [4]	82	3. 5*	3. 1*	6. 6*	2. 5	2. 2*	4. 7*
Lindane	30	5. 1	4. 3	9. 4	2. 7	2. 7	5. 4
Toxaphene	150	6. 3	5. 0	11. 3	3. 3	3. 2	6. 5
Dilan	120	6. 1	5. 1	11. 2	2. 8	2. 7	5. 5
DDT	30	4. 9	3. 7	8. 6	2. 6	2. 6	5. 2
TDE	30	5. 2	4. 5	9. 7	2. 5	2. 7	5. 2
Malathion	120	5. 8	4. 9	10. 7	3. 0	2. 8	5. 8
None	----------	5. 6	4. 7	10. 3	3. 3	3. 0	6. 3
L. S. D. at 5-percent level [5]	----------	2. 2	1. 5	3. 4	(7)	0. 8	1. 8
L. S. D. at 5-percent level [6]	----------	1. 7	1. 1	2. 8	(7)	0. 6	1. 5

Insecticide	Total insecticides	Carrots [3]			Turnips [3]		
		Roots	Tops	Total	Roots	Tops	Total
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Aldrin	30	4. 5	1. 9	6. 4	7. 7	1. 9	9. 6
Dieldrin	30	4. 8	1. 8	6. 6	8. 7*	2. 0	10. 7
Isodrin	30	4. 9	1. 7	6. 6	8. 1	2. 0	10. 1
Endrin	30	5. 1	2. 5	7. 6	8. 7*	2. 1	10. 8*
Chlordane	120	4. 8	1. 7	6. 5	8. 9*	2. 2	11. 1*
Heptachlor	120	5. 1	2. 1	7. 2	9. 3*	2. 3	11. 6*
BHC, technical [4]	82	4. 8	2. 1	6. 9	9. 0*	1. 6	10. 6
Lindane	30	5. 1	2. 2	7. 3	10. 2*	2. 2	12. 4*
Toxaphene	150	4. 9	2. 1	7. 0	8. 7*	1. 8	10. 5
Dilan	120	5. 0	2. 3	7. 3	9. 3*	2. 2	11. 5*
DDT	30	5. 3	2. 1	7. 4	7. 8	1. 9	9. 7
TDE	30	5. 2	2. 4	7. 6	9. 3*	1. 4	10. 7
Malathion	120	5. 4	1. 8	7. 2	7. 7	2. 2	9. 9
None		5. 0	2. 2	7. 2	6. 0	1. 4	7. 4
L. S. D. at 5-percent level [5]		(7)	(7)	(7)	3. 3	(7)	4. 1
L. S. D. at 5-percent level [6]		(7)	(7)	(7)	2. 7	(7)	3. 4

[1] *=significant at the 5-percent level.
[2] Sprayed.
[3] Beans, carrots, and turnips grown simultaneously and not sprayed, immediately following sprayed beans.
[4] Total isomers added.
[5] For comparisons among treatments.
[6] For comparisons between treatment versus no treatment.
[7] Not significant.

TABLE 16.—*Accumulation of insecticides in soil after foliage applications to successive crops of Stringless Black Valentine snap bean in the field, New Brunswick, N. J., 1952–54*

Insecticide applied	Recovery of organic chlorine from soil in percentage of total pounds per acre of material applied	
	Total applied	Amount remaining [1]
	Pounds	*Percent*
Aldrin	30	20
Dieldrin	30	35
Isodrin	30	20
Endrin	30	32
Chlordane	120	21
Heptachlor	120	23
BHC [2]	82	6
Lindane	30	9
Toxaphene	150	43
DDT	30	44
TDE	30	45
Dilan	120	29

[1] Percentages of amount applied that remained in the surface 6 inches of soil.
[2] Total isomers added.

DISCUSSION

In the cooperative tests the tendency for residues of all the insecticides to accumulate under outdoor conditions was substantially greater at Beltsville than at State College, Miss., and a little greater than at New Brunswick, N. J. It is not known to what extent these differences were caused by differences in the soils, the climates, the time of exposure on leaf or soil surfaces before being covered with soil, and the experimental procedures. Each of those factors may have had some effect. Furthermore, in the cooperative tests at Beltsville the tendency to accumulate was more marked on Congaree loam than in the earlier design in coldframes on Chester loam. Since these two tests were partly concurrent with no very noticeable differences in weather among years, it is probable that soil differences were partly responsible. Certainly it appears unsafe to predict how much of a substance may accumulate in one district or in one soil on the basis of results obtained in a very different place and on other kinds of soil. Many years will be required for the gradual accumulation of a body of evidence under a wide range of conditions before accurate predictions can be made. In the meantime, in the absence of definite data, it would seem to be wise to use the insecticides discussed here as though they might accumulate at the more rapid rates observed.

Since many workers had accumulated a considerable body of evidence on the high tendency of DDT to accumulate in the soil, DDT was omitted from some of these tests in order to make room for newer and less known substances. At the time these studies were started there was much interest in heptachlor, aldrin, dieldrin, and others of that family in comparison with such substances as toxaphene that are normally used in much larger dosages.

For the control of many pests with aldrin, chlordane, or heptachlor, recommended dosages are not likely to result in total annual applications in excess of 2 to 3 pounds. For many pests annual use of insecticides would be less, and for a few insects it would be more. At 2 to 3 pounds per acre per year and the probable rate of disappearance indicated in this bulletin, it appears extremely unlikely that residues of these 3 insecticides would ever accumulate in the soil to the extent that they would impair growth of any crops included in the tests reported here.

Less is known about isodrin and endrin than the other substances studied, but they appear much more likely to accumulate residues than aldrin, chlordane, and heptachlor, with isodrin much less stable than endrin. Endrin, in these studies, appears thus far to tend to accumulate to about the same degree as DDT under some conditions. While DDT is so persistent as to present a definite hazard as a soil residue to growth of some crops under some conditions, the probable common annual applications of isodrin and dieldrin are much lower than those of DDT and therefore they will accumulate much slower than DDT on an absolute basis. Dieldrin appears to be more persistent than aldrin but less persistent than endrin, and dieldrin also will be used at a very low rate per acre.

In this study toxaphene has appeared to be a substance that may accumulate to a considerable extent, only a little less than DDT. Evidence available a few years ago suggested to some workers[6] that toxaphene is much less stable than DDT. It is, however, far more stable than BHC, lindane, chlordane, and related substances and nearly as stable as DDT. Furthermore, it is used at rates considerably higher than BHC, lindane, and chlordane and therefore much larger quantities may accumulate in the soil following frequent and continued use. Even so, in this study the soil residue accumulated was rarely high enough to harm the few unsprayed test crops significantly.

BHC preparations containing large quantities of isomers other than the gamma isomer may accumulate sufficiently to impair growth of sensitive crops, but lindane properly used does not appear likely to do so. This statement applies only to crop growth. Although BHC and lindane accumulate to the least extent of any of these substances studied, there is still some doubt about the probable effects of use of any BHC preparation on the quality of root crops grown subsequently on fields that have grown BHC-treated crops. Also, pound for pound, BHC is perhaps the most generally harmful to growth among the substances studied here.

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[6] See footnote 3, p. 1.

None of these reported results should be interpreted as assurance that the edible parts of any particular crop will remain free of contamination by such amounts of an insecticide or its decomposition products that will accumulate in the soil.

Although considerable quantities of organic chlorine were found in carrots grown on plots receiving most of the treatments applied to preceding crops, a great deal of work remains to be done to determine definitely the safety or hazards of such treatments in connection with food plant production.

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