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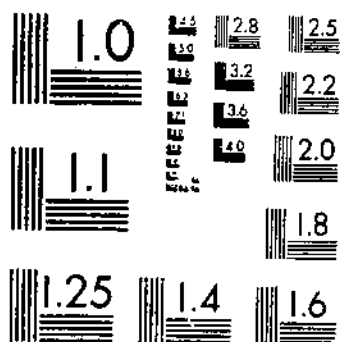
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EFFECT ON TRUCK CROPS OF DDT APPLIED TO THE FOLIAGE
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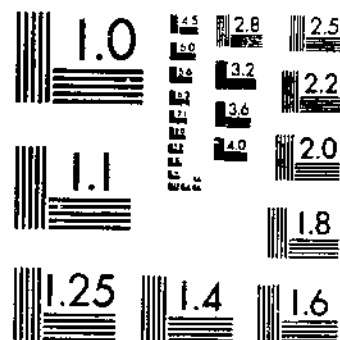
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NATIONAL BUREAU OF STANDARDS-1963-A



UNITED STATES
DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

Effect on Truck Crops of DDT Applied to the Foliage

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INTRODUCTION

DDT first became generally available for experimental use as an insecticide in 1943, soon after its remarkable effectiveness in the control of certain insects affecting man and animals had been reported. In 1943 and 1944 DDT was tested by various workers throughout the country against a large number of crop pests. The results were so outstanding that it became desirable to study the effect of the insecticide on the plants.

Experiments on the tolerance of truck crops to DDT were therefore conducted at Beltsville, Md., from 1945 to 1948, inclusive. One or more experiments were run on each of the following crops: Snap bean, lima bean, beet, cabbage, cantaloup, cucumber, onion, garden pea, Irish potato, summer squash, Hubbard squash, tomato, and turnip.

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² Acknowledgment is made to Victor R. Boswell, Bureau of Plant Industry, Soils, and Agricultural Engineering, for helpful advice and assistance.

The primary objective of the studies was to determine the direct effect of DDT on plant growth and crop yield when applied to the foliage at different strengths and dosages. The DDT was applied as sprays and dusts. The strengths and dosages and the number of applications were the maximum believed necessary for seasonal control of the insects involved. Another objective was to determine whether any of the DDT applied to the foliage is absorbed and translocated to the edible portions of the plants.

REVIEW OF LITERATURE

Numerous reports have been made of applications of DDT dusts and sprays to the foliage of various truck crops. Foliage injury has been reported in a few instances. The New Jersey Agricultural Experiment Station (5)^a reported injury to squash, cantaloup, cucumber, snap bean, and tomato. White (9), in summarizing the results of field experiments conducted in 1945 with DDT in several States, reported injury under some conditions to squash, cucumber, and pumpkin by DDT dusts. Bruce and Tauber (1) found that 3-percent DDT dust injured acorn squash and muskmelon, but not potato, cabbage, Hubbard squash, or Buttercup squash. In tests conducted by Dudley (3) during 1944, 1945, and 1946, in which DDT dusts, and in one experiment DDT sprays, were applied to 56 or more horticultural varieties of truck crops in small field plots, foliage injury was observed on several varieties of cucumber and squash.

GENERAL PROCEDURE

EXPERIMENTAL DESIGN

A separate randomized-block experiment with eight replicates was conducted for each crop each year the crop was tested. Each plot was 35 feet long and at least 10 feet wide with three to eight rows.

From two to four DDT preparations were compared with a treated check and sometimes with an untreated check in each experiment. The formulations, strengths, and schedules of application were varied according to the pests that ordinarily need to be controlled on the respective crops. Heavy dosages of DDT were tested so as to approximate the maximum dosage for possible commercial use. Insects in the treated checks were controlled by applications of rotenone, pyrethrum, cryolite, or tartar emetic.

When infestations of the Mexican bean beetle (*Epilachna varivestis* Muls.) or of other insects developed on the DDT-treated plots of an experiment, all the plots in the experiment were dusted or sprayed with rotenone. This precaution was taken to aid in the determination of any direct effects of DDT exclusive of insect damage.

CULTURAL METHODS

The crops were grown in either of two fields west of Little Paint Branch on the North Farm of the Plant Industry Station at Beltsville.

^a Italic numbers in parentheses refer to Literature Cited, p. 20.

Field A was on a hillside, and the soil was an association of Delanco and Gibbstown loamy sand about 9 inches deep and with good or excessive drainage. Field B was on a lower terrace along the branch, and the soil was Codoris silt loam about 10 or 12 inches deep, imperfectly drained internally but with good surface drainage. Overhead irrigation was used in both fields as needed.

The beets, cabbage, onions, peas, turnips, lima beans, and the 1945 plantings of snap beans and potatoes were in field A. The other plantings of snap beans and potatoes and all the plantings of tomatoes, cucumbers, cantaloups, and squash were in field B.

Conventional methods of soil preparation were used, and approximately 1,000 pounds per acre of 5-10-5 commercial fertilizer was worked into the soil before each crop was planted. Ground dolomitic limestone was applied when required. Seed was sown with a single-row garden planter; squash, cucumber, and cantaloup were planted by hand in hills and covered with a hoe; transplants were set out by hand and watered when necessary. Flat culture was practiced throughout, except that potatoes were ridged slightly at the late cultivations.

The number of rows and the distances between rows and between plants or hills for each of the several crops are shown in table 1.

TABLE 1.—*Plot data for studies on the effect of DDT on vegetable crops*

Crop	Rows per plot	Distance between—	
		Rows	Plants or hills in rows
	Number	Feet	Feet
Bean, lima.....	4	3	$\frac{1}{2}$
Bean, snap.....	4	$2\frac{1}{2}$	$\frac{1}{2}$
Beets.....	4	$2\frac{1}{2}$	$\frac{1}{2}$
Cabbage.....	4	3	$1\frac{1}{4}$
Cantaloup.....	3	4	5
Cucumber.....	3	4	5
Onion.....	5	2	$\frac{1}{2}$
Pea.....	5	2	$\frac{1}{2}$
Potato.....	4	3, $3\frac{1}{2}$, $3\frac{1}{2}$	1
Squash, summer and winter.....	4	4, 5	5
Tomato.....	4	4, 5	4
Turnip.....	5 to 8	$1\frac{1}{2}$, $2\frac{1}{2}$	$\frac{1}{2}$, $\frac{1}{2}$

Unless otherwise indicated, plants from the outside rows of each plot and those within 5 feet of each end were excluded from the yield records. Because of the shortage of manpower in 1945 and 1946, it was impossible to harvest each of the test crops often enough to obtain products of the best market quality. Instead of successive pickings of bean pods, cucumbers, and cantaloups, pullings of beets and turnips, and cuttings of cabbage, each of these crops was allowed to mature a little beyond market stage and a single harvest was made. Successive harvests of tomatoes and squash were at longer than normal intervals and some of the produce was overmature.

All quantitative data were analyzed by the variance method for randomized blocks, and least significant differences were calculated wherever indicated.

MATERIALS AND EQUIPMENT

When this work was begun in 1945, little was known about the dosages or formulations of DDT that might be required to control a particular insect affecting plants. From 1945 to 1948 the methods of manufacture and formulation were undergoing change, and as knowledge was acquired dosages or formulations applied to the several crops were also changed.

The DDT dusts were prepared from commercial 10-percent DDT except in 1945, when some of the dusts contained about 20 percent of DDT. When necessary, pyrophyllite was used for further dilution in 1945 and talc from 1946 to 1948.

The suspension sprays were prepared from commercial wettable powders containing 51.8 percent of DDT except in 1945, when the simple 10- to 20-percent dusts were used, without wetting agents.

The emulsion spray was prepared from refined DDT dissolved in xylene and emulsified with polyethylene glycol phenyl isooctyl ether.

The cryolite, tartar emetic, and sulfur were well-known standard grades.

The pyrethrum dusts used in 1945 were prepared from ground pyrethrum flowers containing 0.67 percent of pyrethrins; the dusts used from 1946 to 1948 were prepared from ground flowers containing about 0.8 percent of pyrethrins. The diluents were the same as those used for DDT. The pyrethrum sprays were prepared from an alcoholic extract containing 2 percent of pyrethrins.

The rotenone sprays used in 1945 were prepared from a cube powder containing 4.7 percent of rotenone and 16.9 percent of total extractives; in 1946 the cube powder contained 5.9 percent of rotenone and 20.9 percent of total extractives; in later years the cube powders ranged within these limits.

The rotenone dust used in 1945 was commercially prepared from cube and contained 1.1 percent of rotenone and 3.1 percent of total extractives. The dust available in 1946 contained only 0.75 percent of rotenone and 2.8 percent of total extractives, and that used in later years contained about 1 percent of rotenone and 3 percent of total extractives. The diluents were the same as those used for DDT. The undiluted cube powders were used in preparing the rotenone-DDT-sulfur mixture applied to beans in 1947 and 1948.

The fungicides used during the 4-year test period were dusting sulfur, ferbam, tribasic copper sulfate, bordeaux mixture, and zineb. Commercial preparations were used as recommended by the manufacturers.

The details of each formulation and the quantities of dust or spray applied per acre are given in the various tables.

The dusts were applied with hand dusters of the rotary or fan type, a separate duster being used for each kind of insecticide. Applications were made between 6 and 8 a. m., before the dew evaporated or winds arose. The sprays were applied with a gasoline-powered

sprayer of the wheelbarrow type at a pressure of 225 pounds per square inch. The number of applications for the season ranged from two for the peas to nine for the squash. Most of the applications were made at intervals of 7 to 10 days, but on squash the first few were made at 5-day intervals.

CHEMICAL ANALYSES

For the study of DDT residues and the possible absorption of DDT by vegetables and translocation into the edible portions, random samples of the vegetables were taken from each replicate and pooled to make a composite sample for each treatment. To permit determinations of approximately 1 p. p. m. to be made with reasonable accuracy, a subsample of 2 to 3 kg. (green weight) of the composite sample was used for each analysis. The results were calculated on the basis of green weights. Bulky wet materials were first dried at 50° to 60° C. with a very slow air current, and then stripped or extracted with benzene in a tumbling machine for at least 1 hour.

Aliquots of the benzene solutions were then analyzed for organic chlorine according to Umhoefer's method (?). Determination of ionic chlorine was made by electrometric titration with silver nitrate. The quantities of DDT were calculated from the quantities of organic chlorine found on the treated samples in excess of that found in the checks. Quantities less than 1 p. p. m. were considered unmeasurable, and in this bulletin are so indicated, or sometimes referred to as traces. Confirmatory tests by the colorimetric method of Schechter, Pogorelskin, and Haller (6) were made in some cases.

EXPERIMENTS

BEANS

Snap beans were tested in 1945 and 1946 and lima beans in 1947 and 1948. The snap beans were planted about the middle of May, and the lima beans about the first of June. The first insecticide application was made when the plants were 8 to 12 inches high. Rotenone spray was applied to all plots alike, as needed for the control of the Mexican bean beetle. Harvest was delayed until 10 to 15 percent of the pods were well beyond the best market stage but not yet ripe or dry. The insecticide treatments, the varieties tested, and the results of these tests are given in table 2.

With the varieties and dosages used there was no clear-cut evidence of either stimulation or depression of growth. There were no significant differences in yields except in 1946, when the yield of Stringless Green Pod snap beans in the DDT-treated plots was significantly greater than in the untreated check plots. This increase in yield may have been due in part to better control of the potato leafhopper (*Empoasca fabae* (Harr.)).

TABLE 2.—*Effect of DDT dusts and sprays on yield of beans, 1945 to 1948*

Material and strength (pounds per 100 gallons of spray or percent of dust)	Dosage per acre		Yield per acre ¹
	Insecticide mixture per application	Total DDT	
BOUNTIFUL SNAP BEANS IN 1915 (5 APPLICATIONS)			
DDT:	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>
2.5 percent.....	26	3.25	3,157
5 percent.....	31	7.68	3,142
0.4 lb. (10-percent dust 4 lb.) plus ferbam 2 lb.....	² 100	2.00	2,939
Checks:			
Pyrethrins 0.15 percent plus sulfur 50 percent.....	34	0	3,154
Untreated.....			3,000
STRINGLESS GREEN POD SNAP BEANS IN 1916 (4 APPLICATIONS)			
DDT:			
3 percent.....	25	2.97	5,851
5 percent.....	28	5.6	6,414
1.25 lb. (51.8-percent wettable powder 2.4 lb.) plus ferbam 2 lb.....	² 111	5.6	5,975
Checks:			
Pyrethrins 0.3 percent plus sulfur 50 percent.....	37	0	5,528
Untreated.....			4,835
Difference required for significance at 5-percent level.....			920
FORDHOOK LIMA BEANS IN 1947 (4 APPLICATIONS)			
DDT:			
3 percent.....	16	1.9	5,471
5 percent.....	17	3.3	5,491
1 percent plus rotenone 0.5 percent plus sulfur 50 percent.....	30	1.2	5,756
Check, pyrethrins 0.3 percent plus sulfur 50 percent.....	25	0	5,404
FORDHOOK LIMA BEANS IN 1948 (4 APPLICATIONS)			
DDT:			
3 percent.....	30	3.6	7,301
5 percent.....	42	8.4	7,606
1 percent plus rotenone 0.5 percent plus sulfur 50 percent.....	44	1.7	7,591
Check, pyrethrins 0.3 percent plus sulfur 50 percent.....	50	0	8,073

¹ Differences not significant according to *F* test except for Stringless Green Pod snap beans.² Gallons.

The pods of Stringless Green Pod snap beans and Fordhook lima beans from the DDT-treated plots were russeted. This injury was only superficial in the lima beans, having no effect on the development or appearance of the shelled beans. Studies by Wester and Weigel (8) show that the Triumph variety of lima bean is extremely sensitive to DDT, its growth being seriously stunted by DDT sprays, whereas other commercial varieties of lima beans tested are not so affected. No russetting appeared, however, on the pods of the Triumph variety.

Except for the potato leafhopper, which was controlled in the plots treated with DDT or pyrethrum, the only insect infestation of importance on either snap beans or lima beans was that of the Mexican bean beetle. This beetle was controlled by applying either a 0.5- to 1-percent rotenone dust or a 0.02-percent rotenone spray to the entire planting as needed. In 1948, however, spider mites (*Tetranychus* sp.) increased during the 6 weeks after the last application on July 30, especially on the DDT-treated plots of lima beans.

In 1945 bean samples for chemical analysis of DDT residues were taken on July 4, 9 days after the second application, and on July 31 and August 20, 8 and 28 days, respectively, after the last application. Subsamples were run by stripping the whole undried beans; other subsamples were dried and ground before extraction with benzene. The amounts of organic chlorine found on the treated samples did not exceed the amounts found on the check samples. This indicates that no DDT was present on the treated samples, either as a residue or as the result of absorption and translocation.

In 1946 similar samples were taken on July 25, 15 days after the last of four applications. Organic-chlorine determinations showed that the DDT residues from the 3- and 5-percent DDT dusts were 0.6 and 0.2 p. p. m. and from the DDT-ferbam spray 1 p. p. m.

The traces of organic chlorine on the treated undried and unground samples were probably due to DDT residues, as the bean pods were not washed before they were stripped.

In 1947 and 1948 organic-chlorine determinations on the unshelled lima beans indicated no measurable residues. Colorimetric determinations for DDT on the shelled dried ground beans were also negative. The samples were taken 25 to 27 days after the last application.

BEETS

Detroit Dark Red beets were planted on April 3, 1946, but the south half of the planting developed a poor stand and had to be replanted, so that each half had a separate treatment and harvest schedule. The first insecticide applications were made when the plants were about 6 inches tall - on May 23 for the north half and on June 21 for the south half. When most of the marketable roots were 2½ to 3 inches in diameter - July 21 for the north half and August 14 for the south half - the beets were pulled by hand, the soil was shaken off, and the beets were weighed.

As analyses of variance showed no significant difference between treatments, the data for the two halves were averaged. Table 3 shows the yields of beets from the several treatments. Although the plots dusted with pyrethrum-sulfur and 3-percent DDT gave lower yields

than the untreated ones, the differences are not significant and are believed to have been due to variations in stand. No injurious or stimulating effect of the treatments could be noted.

The insect-population counts indicated that the insects present were too few to be of much consequence. The quality of the beets was somewhat reduced by feeding scars caused by flea beetle larvae.

Samples of beets for analysis were washed, peeled, sliced, and dried. No measurable amounts of organic chlorine were found in any of the samples taken 26 and 33 days after the last application of DDT, an indication that there was no absorption or translocation of the DDT.

TABLE 3.—*Effect of DDT dusts and sprays on yield of beets, cabbage, cantaloups, cucumbers, and onions, 1945 and 1946*

Material and strength	Dosage per acre		Yield per acre ¹
	Insecticide mixture per application	Total DDT	
DETROIT DARK RED BEETS IN 1946 (4 APPLICATIONS)			
DDT:	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>
3 percent	23	2.8	36,016
5 percent	27	5.4	40,389
10 percent	38	15.4	41,658
Checks:			
Pyrethrins 0.3 percent plus sulfur 50 percent	20	0	35,472
Untreated			41,215
GOLDEN ACRE CABBAGE IN 1945 (4 APPLICATIONS)			
DDT:			
2.5 percent	35	3.5	22,255
5 percent	29	5.0	21,066
Checks:			
Rotenone 1 percent	31	0	20,427
Untreated			19,788
GOLDEN ACRE CABBAGE IN 1946 (4 APPLICATIONS)			
DDT:			
3 percent	20	2.4	14,745
5 percent	22	4.1	16,148
Checks:			
Rotenone 1 percent	20	0	14,201
Untreated			14,723
HALE'S BEST CANTALOUPS IN 1945 (8 APPLICATIONS)			
DDT:			
5 percent	18	6.2	8,169
10 percent	31	21.5	6,284
Check, rotenone 1 percent	24	0	7,580
Difference required for significance at 5 percent level			1,096

See footnotes at end of table.

TABLE 3.—*Effect of DDT dusts and sprays on yield of beets, cabbage, cantaloups, cucumbers, and onions, 1945 and 1946—Continued*

Material and strength	Dosage per acre		Yield per acre ¹
	Insecticide mixture per application	Total DDT	
ABBOTT AND CORB CUCUMBERS IN 1945 (8 APPLICATIONS)	Pounds	Pounds	Pounds
DDT:			
5 percent.....	² 28	9.9	5,616
10 percent.....	² 31	21.8	5,537
Check, rotenone 1 percent.....	² 25	0	4,787
EBENEZER ONIONS IN 1945 (6 APPLICATIONS)			
DDT:			
5 percent.....	29	8.6	24,584
10 percent.....	38	22.9	25,041
0.5 lb. per 100 gal. of spray (in emulsion).....	² 81	1.9	23,315
Checks:			
Tartar emetic 2 lb. plus brown sugar 4 lb. per 100 gal. of spray.....	³ 100	0	21,486
Untreated.....			23,086

¹ Differences in yield not significant according to the *F* test except for cantaloups.

² Small quantity applied to seedling plants (initial application) not included.

³ Gallons.

CABBAGE

In 1945 Golden Acre cabbage was transplanted on March 25 and in 1946 on April 3. The first insecticide treatments were made when the plants were 7 to 8 inches in diameter. Cabbage heads were allowed to stand as long as feasible before harvest without appreciable loss of heads from bursting. All heads were harvested and weighed on June 5 and 22 in 1945, and on June 11 and 18 in 1946. The heads were cut close, including only those leaves that clung tightly to the head.

The growth of cabbage, as indicated by the yields in table 3, was remarkably the same with all treatments in both 1945 and 1946. There was no evidence that any of the treatments were harmful or caused any stimulation. The quality of crops, however, was far better on the DDT-treated plots than on the others because of better control of the imported cabbageworm (*Pieris rapae* (L.)) and the diamondback moth (*Plutella maculipennis* (Curt.)).

The yields include such heads as were damaged by caterpillars, as well as the marketable heads. There was no evidence that insects affected these values.

In 1945 analysis of wrapper leaves from samples taken 6 days after the last application showed 1 p. p. m. of DDT from the plots receiving 2.5-percent DDT and 6 p. p. m. from those receiving 5-percent DDT.

Cabbage heads without wrapper leaves from the same plots showed 4 and 5 p. p. m. of DDT, respectively.

In 1946, 1.2 p. p. m. of DDT was found in a sample of heads plus wrapper leaves taken 11 days after the last application of the 5-percent DDT dust, whereas none was found in a sample of cabbage treated with the 3-percent dust. Similar samples taken 18 days after the last application gave negative results.

CANTALOUPE

In 1945 Hale's Best cantaloupe seed was planted on May 19, and the first insecticide applications were made on June 15, when the seedlings were 4 to 5 inches high and still in the cotyledon stage. Frequent rainfall and high humidity caused the plants in all plots to be severely mildewed. A few days after the first fruits were ripe, it was evident that growth would not be normal. Therefore, on August 22 all mature fruits were harvested regardless of ripeness.

Table 3 shows the yield per acre of fruits harvested from each treatment. The 10-percent DDT dust caused a significantly lower weight of fruits than did the 5-percent DDT or the rotenone dust. Numbers of fruits harvested per treatment were roughly comparable with weight harvested, but the differences were not significant. It is perhaps worth noting that the 10-percent dust produced fruits averaging less than 1 pound each, whereas fruits from the other two treatments averaged more than 1 pound. These data indicate that the heavier application of DDT actually retarded growth and development to some extent.

The inroads of disease so impaired the quality of the crop that no dependable comparisons could be made between treatments. The pickleworm (*Diaphania nitidalis* (Stoll)) was present but not in sufficient numbers to affect the yields.

On August 22, 15 days after the last application, 2.5-kg. fruit samples were taken, and the flesh only was dried and analyzed. No measurable quantities of organic chlorine were found.

CUCUMBERS

Abbott and Cobb cucumber seed was planted on May 19, 1945, and, as on other cucurbits, the first insecticide applications were made on June 15, when the plants were still in the cotyledon stage. Because of damage by mildew, a single delayed harvest was made on August 18. None of the fruits had turned yellow with maturity, but some were too large and too old to be of good quality. All fruits of marketable size in each plot were weighed together. The DDT treatment did not significantly affect the yield (table 3) or the appearance as market quality of the cucumbers. Because of low infestations, insects were not a factor in this experiment.

Incidental to this experiment, a dust containing 70 percent of tri-basic copper sulfate in talc was used on the cucumbers on one side of the planting to control mildew. Yields were 70 percent higher in the treated area than in the plots where no fungicide was used.

Samples for chemical analysis were taken on August 14, 6 days after the last application. In one set of samples the cucumbers were stripped (whole) with benzene, and in another set they were washed.

sliced, dried, and then extracted. No measurable amounts of organic chlorine were found.

ONIONS

Ebenezer onion sets were planted in the field plots on March 16, 1945. The first insecticide applications were made on May 7, when the new shoots were about 6 to 8 inches tall. Harvesting was done on July 10.

The foliage in the DDT-treated plots remained cleaner and more attractive than that in the other plots throughout the experiment. This was due to the control of the onion thrips (*Thrips tabaci* (Lind.)), which was not adequately controlled with tartar-emetic spray. The DDT emulsion spray soon imparted an oily appearance to the foliage, but after the spray dried this condition disappeared with no apparent harm to the plants. As shown in table 3, there were no significant differences in the yields. Thus, there is no clear indication that DDT had either an injurious or direct stimulating effect on the onions.

Onion samples for chemical analysis were taken on July 4, 1945, 10 days after the last application. The onions were conditioned in the greenhouse for several weeks and then dried, cut up, extracted, and analyzed. No measurable quantities of organic chlorine were found in any of the treated samples.

PEAS

Alaska peas were planted on April 20, 1945, and Thomas Laxton peas on March 7, 1946. They were dusted for the first time when the plants were about to blossom—on May 26 in 1945 and on May 6 in 1946. They were harvested by hand when most of the peas were ready for canning—on June 16 in 1945 and on June 6 in 1946. The pods and vines were weighed separately.

In 1945 there were no significant differences in yield of unshelled peas (table 4) or of vines (not shown in table) among the several treatments. In 1946 the 10-percent DDT dust treatment outyielded the other treatments in weight of unshelled peas, but the weights of vines again showed no significant differences. The reason for the superior yield with this dust is not clear. It gave the best control of the pea aphid (*Macrosiphum pisi* (Klth.)) in both years, and in 1946 the pods were greener and more attractive than those from other plots.

There was no indication that the dosages of DDT used had any harmful effect on the pea crops, or any beneficial effect beyond that possibly associated with aphid control.

In 1945 samples of pea vines for chemical analysis were taken from each treatment 16 days after the last application. In 1946 samples were taken 8 and 14 days after the last application. The vines were analyzed both green and after having been dried in the greenhouse. The shelled peas were dried, ground, and then analyzed. No measurable quantities of organic chlorine were found on the shelled peas for either year.

The DDT residues were 0 and 1.1 p. p. m. on the green vines harvested 16 days after dusting with 5- and 10-percent DDT dusts, respectively, in 1945, and 1.6 and 3.4 p. p. m. on green vines harvested 8 days after dusting with the two mixtures, respectively, in 1946.

TABLE 4.—*Effect of DDT dusts on yield of unshelled peas, 1945 and 1946*

Material and strength	Dosage per acre		Aphids surviving per sweep	Yield per acre
	Insecticide mixture per application	Total DDT		
ALASKA IN 1945 (2 APPLICATIONS)	Pounds	Pounds	Number	Pounds
DDT:				
5 percent.....	32	3.2	31	5,767
10 percent.....	29	5.9	16	6,382
Checks:				
Rotenone 1 percent.....	33	0	14	6,451
Untreated.....			90	5,732
Difference required for significance at 5-percent level.....			11	(¹)
THOMAS LAXTON IN 1946 (2 OR 3 APPLICATIONS)				
DDT:				
5 percent.....	59	7.3	9	8,782
10 percent.....	57	14.3	6	10,193
Checks:				
Rotenone 1 percent.....	66	0	17	8,483
Untreated.....			32	8,391
Difference required for significance at 5-percent level.....			7	1,347

¹ Difference not significant according to the *F* test.

POTATOES

The Irish Cobbler potatoes were planted late in March or early in April, and the first insecticide applications were made when the foliage was about 6 inches high. The Katahdin and Sebago varieties used in 1947 were planted on June 23 and treated for the first time on July 15.

The Irish Cobblers were harvested about the middle of July, when the tubers were well-grown and the tops showed evidence of approaching maturity. The fall crop was harvested on September 30, 1947, when top growth had almost ceased. Twenty-five successive hills were harvested from each of the two center rows of each plot, and the weight per plot was recorded. All plots were usually harvested within 1 day.

In the springs of 1945 and 1946 moderate but significant increases in yield over the check plots were obtained with certain of the DDT sprays and the 5-percent DDT dusts. In the plots not treated with DDT or pyrethrum, however, most of the leaflets showed hopperburn caused by the potato leafhopper (*Empoasca fabae* (Harr.)). The data in table 5 show that DDT greatly reduced this damage. Therefore, it is believed that the increased yields in the DDT-treated plots were due to leafhopper control rather than to any direct stimulative

TABLE 5.—*Effect of DDT dusts and sprays on yield of potatoes, 1945 to 1948*

Materials and strength (pounds per 100 gallons of spray or percent of dust) ¹	Dosage per acre		Leaflets with hopper-burn	Yield per acre
	Insecticide mixture per application	Total DDT		
IRISH COBBLER IN 1945 (6 APPLICATIONS)	Gallons	Pounds	Percent	Pounds
DDT:				
5 percent.....	2.28	7.3	50	15,697
0.4 lb. (10-percent dust without wetting agent 4 lb.).....	103	2.5	57	14,889
0.4 lb. plus tribasic copper sulfate.....	93	2.2	64	13,889
Checks, rotenone (3.4 lb. of 4.7 percent) plus tribasic copper sulfate.....	95	0	95	12,354
Difference required for significance at 5-percent level.....			14	2,293
IRISH COBBLER IN 1946 (3 APPLICATIONS)				
DDT:				
5 percent.....	2.33	13.0	6	28,642
0.625 lb. (1.2 lb. of 51.8-percent wettable powder).....	173	8.6	5	27,726
0.625 lb. plus tribasic copper sulfate.....	165	8.2	6	24,474
Checks:				
Rotenone (2.7 lb. of 4.5 percent) plus pyrethrum (1.6 pt. of 2-percent extract) plus tribasic copper sulfate.....	150	0	34	24,090
Untreated.....			85	23,010
Difference required for significance at 5-percent level.....			7	2,353
KATAHDIN AND SEBAGO (LATE CROP) IN 1947 (6 APPLICATIONS)				
DDT:				
5 percent.....	2.20	8.7		15,286
0.625 lb. (1.2 lb. of 51.8-percent wettable powder).....	138	5		17,272
0.625 lb. plus tribasic copper sulfate.....	135	5		16,627
0.625 lb. plus zincb.....	132	5		17,160
Checks, rotenone (1.93 lb. of 5.3 percent) plus pyrethrum (1.6 pt. of 2-percent extract) plus fungicide 2 lb. ³	123	0		17,819
Difference required for significance at 5-percent level.....				(⁴)
IRISH COBBLER IN 1948 (4 APPLICATIONS)				
DDT:				
5 percent.....	2.22	4.4		14,218
1.25 lb. (2.4 lb. of 51.8-percent wettable powder).....	100	5.5		14,389
1.25 lb. plus tribasic copper sulfate.....	97	4.9		14,691
1.25 lb. plus zincb 2 lb.....	94	4.7		14,765
Checks, rotenone (2.7 lb. of 4.5 percent) plus pyrethrum (1.6 pt. of 2-percent extract) plus fungicide 2 lb. ³	100	0		13,404
Difference required for significance at 5-percent level.....				(⁴)

¹ Tribasic copper sulfate used at 4 pounds; other fungicides at 2 pounds.² Pounds.³ A commercial preparation containing 33 percent each of zincb and methyl dithiocarbamate.⁴ Differences in yield not significant according to *F* test.

effect of DDT. This belief is confirmed by the lack of any significant differences in yield during 1947 and 1948, when few leafhoppers were present. The only other insect that caused appreciable injury was the potato flea beetle (*Epitrix cucumeris* (Harr.)), the larvae of which damaged some of the tubers in 1947. The yields shown in table 5 include these damaged tubers.

In 1946 DDT treatments were followed by a bronzing of the leaves believed to be a mild injury by DDT. In 1945 and 1947 no injury that could be attributed to DDT was noted. Furthermore, in those years the foliage treated with DDT appeared brighter and cleaner than that in the check plots.

Samples of potatoes from all the plots receiving the insecticide treatments for each of the 4 years were washed, peeled, sliced, dried, and analyzed for organic chlorine. In 1947 and 1948 colorimetric determinations for DDT were also made. No measurable quantities of organic chlorine were found. The colorimetric tests were also negative. These tests indicated that DDT was not taken up by the plants and translocated to the tubers.

SQUASH

The squash was planted the latter part of May, and insecticides were first applied while the plants were in the cotyledon stage, at which time they are subject to damage by cucumber beetles (*Diabrotica* spp.). The summer squash was harvested approximately at 10-day intervals in August and September, there being three harvests in 1945 and five in 1946. The Hubbard winter squash was harvested on October 8, 1946. The entire crop was harvested each time.

The total yields of squash in 1945 (table 6) do not fully show the actual response of the Yellow Summer (Crookneck variety) to DDT. The first applications of the 10-percent DDT dusts, both with and without sulfur, killed so many of the newly emerged plants that considerable replanting was necessary. The surviving plants and the replants were stunted, and the yields at first harvest were significantly reduced. By the end of the season the survivors had made some recovery but generally appeared inferior to the plants on the other treated plots. The DDT-fungicide spray did not cause any noticeable injury. The stands were irregular and varied both among and within treatments, thereby contributing to an extremely high error in 1945. Thus, although the plots treated with 10-percent dust appeared to yield 2,800 to 3,200 pounds per acre less than the checks, the differences were not significant.

In 1946 the content of DDT in the dusts was reduced to 5 and 3 percent. Neither of these dusts caused any apparent injury to Yellow Summer Crookneck squash or difference in yield compared with the rotenone check. The spray, however, caused serious injury similar to that caused in 1945 by the 10-percent dust. Soon after the first application, sprayed plants became stunted, yellowed, and many died. More plants died later. The survivors made from poor to fair growth, and yields were only about one-third as large as in the other plots. Many of the sprayed plants that survived were entirely unfruitful. Because in 1945 practically the same dosage of DDT as a suspension spray

without a wetting agent did not cause injury, it seems possible that this injury was caused by the wetting agent rather than by the DDT, although it may have been due to better coverage.

TABLE 6.—*Effect of DDT on yield of squash, 1945 and 1946*

Material and strength (pounds per 100 gallons of spray or percent of dust)	Dosage per acre		Yield per acre ¹
	Insecticide mixture per application	Total DDT	
YELLOW CROOKNECK IN 1945 (9 APPLICATIONS)			
DDT:	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>
10 percent.....	23	18.4	11,500
10 percent plus sulfur.....	17	14	11,034
0.4 lb. plus tribasic copper sulfate 4 lb. ²	3.478	2.5	15,428
Check, rotenone 1 percent.....	27	0	14,262
YELLOW CROOKNECK IN 1946 (8 APPLICATIONS)			
DDT:			
3 percent.....	18	4.3	13,764
5 percent.....	17	6.7	15,124
3 percent plus pyrethrins 0.3 percent.....	20	4.7	15,323
0.625 lb. (1.2 lb. of 51.8-percent wettable powder).....	4.45	2.3	5,192
Check, rotenone 1 percent.....	14	0	15,707
Difference required for significance at 5 percent level.....			2,492
HUBBARD IN 1946 (8 APPLICATIONS)			
DDT:			
3 percent.....	19	4.5	2,030
5 percent.....	13	5.3	2,022
3 percent plus pyrethrins 0.03 percent.....	15	3.7	1,898
0.625 lb. (1.2 lb. of 51.8-percent wettable powder).....	4.39	2.0	2,131
Check, rotenone 1 percent.....	15	0	1,960

¹ Differences in yield not significant according to the *F* test, except for Yellow Crookneck Squash in 1946.

² Spray prepared from 10-percent dust. No wetting agent used; 2 pounds of ferbam substituted for the tribasic copper sulfate in eighth application.

³ Small quantity applied to seedling plants (initial application) not included.

⁴ Gallons.

A clay dust containing 10 percent of DDT applied to a nearby planting of sugar pumpkin caused rather severe injury and yellowing of the foliage.

In 1946 Winter Hubbard squash was given the same treatments as the summer squash, but without any injurious effect. There were also no significant differences in the yields of this variety.

In 1946 the insect infestations were too low to affect the yield data, which included the insect-damaged squash. In 1945 the pickleworm

and the squash bug (*Anasa tristis* (Deg.)) caused considerable damage, and evidently reduced the yields, particularly in the check plot and in the sprayed plots. Because of these reductions in yield, the differences between the check and the treated plots are not so large as they should be and therefore do not represent all the damage caused by the DDT.

In 1945 samples of Yellow Crookneck squash for chemical analyses were taken 1 day after the last of nine applications and in 1946 6 days after the last of six applications. The samples were peeled, and the flesh only was sliced, dried, and then analyzed. No measurable quantities of DDT were found.

TOMATOES

The Rutgers variety of tomatoes was used for the 1946 tests, and Marglobe in the other 3 years. The transplants were usually set out in the field after the middle of May, when the danger of frost was past. Insecticide applications were begun late in May or early in June, when the plants were from 12 to 18 inches in diameter and setting fruit. Soon after the transplanting, rotenone spray or dust was applied to all plots to control the Colorado potato beetle (*Leptinotarsa decemlineata* (Say)) and the potato flea beetle. Green-mature and ripe fruit was harvested three to four times each season. The entire plots were harvested.

In the 4 years' work with tomatoes the only significant differences in yield were in 1947, when the plots dusted with 10-percent DDT produced more tomatoes than those sprayed with DDT suspension (table 7). None of the treatments, however, significantly affected the yield in comparison with the untreated check.

Slight, apparently temporary, injury to tomato foliage by the DDT sprays was observed in two instances. In 1946 a peculiar proliferation at the tips of the branches suggested the kind of abnormality that follows treatment with certain growth-regulating chemicals. In 1947 a temporary yellowing of the leaves followed the second application of the DDT-copper fungicide spray. The yields tended to be lower where these injuries were observed, but they were not significantly lower than those in the untreated check.

Although light infestations of the tomato fruitworm (*Heliothis armigera* (Hbn.)) and the potato aphid (*Macrosiphum solanifolii* (Ashm.)) usually developed, they never affected the growth of the plants or the yield.

Samples of whole tomatoes from the treated and untreated plots were analyzed for surface residue; similar samples were peeled, sliced, dried, and extracted, and the extracts analyzed for absorbed DDT. Small amounts of residue (less than 0.5 p. p. m.) were found on the surface in some samples, and less than 0.1 p. p. m. was indicated in some of the peeled samples. The DDT in the peeled fruits was confirmed by colorimetric tests, but its presence was probably due to contamination from the surface during peeling.

TABLE 7.—*Effect of DDT dusts and sprays on yield of tomatoes, 1945 to 1948*

Material and strength (pounds per 100 gallons or percent of dust) ¹	Dosage per acre		Yield per acre ²
	Insecticide mixture per application	Total DDT	
MARGLOBE IN 1945 (7 APPLICATIONS)			
DDT 10 percent:	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>
Alone.....	24	17	13, 548
Plus sulfur 20 percent.....	19	13	15, 607
0.4 lb. (10-percent dust 4 lb.) plus tribasic copper sulfate ³	⁴ 99	3	14, 843
Check, cryolite 70 percent plus sulfur 20 percent.....	26	0	14, 261
MARGLOBE IN 1947 (5 APPLICATIONS)			
DDT 10 percent:			
Alone.....	23	11	39, 397
Plus sulfur 20 percent.....	19	10	38, 209
3 lb. (51.8-percent wettable powder 5.6 lb.) plus tribasic copper sulfate.....	⁴ 76	11	33, 088
Checks:			
Cryolite 70 percent plus sulfur 20 percent.....	20	0	35, 980
Untreated.....		0	36, 182
Difference required for significance at 5 percent level.....			4, 209
MARGLOBE IN 1948 (6 APPLICATIONS)			
DDT 10 percent:			
Alone.....	23	14	15, 093
Plus sulfur 20 percent.....	18	11	16, 093
3 lb. (5.6 lb. of 51.8-percent wettable powder) plus tribasic copper sulfate.....	⁴ 62	11	17, 870
Checks:			
Cryolite 70 percent plus sulfur 20 percent.....	28	0	15, 037
Rotenone 1 percent.....	16	0	16, 971
RUTGERS IN 1945 (7 APPLICATIONS)			
DDT 10 percent:			
Alone.....	21	15	21, 049
Plus sulfur 20 percent.....	20	14	17, 110
1.5 lb. (2.8 lb. of 51.8-percent wettable powder) plus tribasic copper sulfate.....	⁴ 61	6. 4	17, 315
Checks:			
Cryolite 70 percent plus sulfur 20 percent.....	17	0	18, 012
Untreated.....			21, 302

¹ Tribasic copper sulfate used at 4 pounds; other fungicides at 2 pounds.² Differences in yield not significant according to the *F* test, except for Marglobe in 1947.³ 2 pounds of ferbam substituted for copper compound in fourth application.⁴ Gallons.

TURNIPS

Experiments with turnips were conducted in 1945 and 1946. The seed was planted each year early in March, and the first insecticide applications were made in April, when the plants were about 6 to 8 inches in diameter. On May 31 of each year, the plants were pulled by hand, the soil was shaken off, and the turnips were weighed.

The yields of turnips (table 8) from the plots dusted with DDT or with rotenone were similar to those from the untreated plots. Neither the 5- nor the 10-percent dust caused any noticeable injury or stimulation of the plants.

In both years the hop flea beetle (*Psylliodes punctulata* Melsh.) was effectively controlled, especially in the DDT-treated plots. In 1946, however, the salable value of the turnips was lowered because of the larval-feeding injury to the roots. The injury was less in the treated plots than in the untreated plots. Turnip aphids (*Rhopalosiphum pseudobrassicae* (Davis)) were also controlled. None of the insects affected the yields.

Samples of turnips for DDT analysis were taken 7 days after the last of five applications in 1945 and 6 days after in 1946. The turnips were washed and peeled, the peelings discarded, and the flesh was sliced, dried, and analyzed. Measurable amounts of organic chlorine were not found in any of the samples.

TABLE 8.—Effect of DDT dusts on yield of Purple Top White Globe turnips, 1945 and 1946

Material and strength	Dosage per acre		Yield per acre ¹
	Insecticide mixture per application	Total DDT	
IN 1945 (5 APPLICATIONS)			
DDT:	Pounds	Pounds	Pounds
5 percent	26	6.5	87,889
10 percent	29	11.3	87,817
Check, rotenone 1 percent	24	0	88,030
IN 1946 (5 APPLICATIONS)			
DDT:	Pounds	Pounds	Pounds
5 percent	25	6.3	32,991
10 percent	30	15.1	34,592
Check:			
Rotenone 1 percent	26	0	35,109
Untreated			32,830

¹ Differences not significant according to the *F* test.

DISCUSSION

In these studies each crop was usually represented by only one or two varieties. Had other varieties been selected, the results might

have been different. For example, Wester and Weigel (8) found that under the same conditions DDT sprays and dusts severely injured Triumph bush limas but not the Peerless variety (a sisterline variety of Triumph). Hervey and Schroeder (4) reported a decided difference between varieties of cucumber in susceptibility to foliage injury from DDT, but did not report any tests with the Abbott and Cobb varieties tested by the authors.

DDT sometimes caused temporary injury to foliage of tomato, bean, and potato, but why this injury was present under some conditions and not under others is not known.

It now appears that the impurities in technical DDT may be an important factor in the injury caused by DDT to squash and related plants. Carruth and Hervey (2) reported more injury to squash by a dust prepared from technical DDT (setting point 90° C.) than by one prepared from a refined grade (setting point 103° to 105° C.). The age of the plants, the quantity of DDT deposited on them, and possibly nutritional and weather conditions may also have contributed to this injury. The weather conditions during the period of these tests were about normal for this area except for the 1945 season, when 15 inches of rain fell during July alone and the other summer months were also rather wet because of frequent showers.

The soil in the plots contained no DDT except that which accumulated from the applications to the foliage during the course of the experiments.

Although chemical analyses indicated traces of DDT inside tomatoes and beans, the quantities were too small to be measurable by the techniques employed. It is believed that the samples were contaminated during preparation for analysis, and that the DDT was not absorbed by the plants and translocated. According to chemical analyses of the other crops, no DDT was absorbed or translocated to the edible portions.

SUMMARY

Field experiments to determine the direct effect of DDT on the plant growth and crop yield when applied to the foliage of various vegetable crops were conducted at Beltsville, Md., from 1945 through 1948. Studies were also made to determine whether any of the DDT applied to the foliage is absorbed and translocated to the edible portions of the plants.

One or more experiments were run on each crop. Each experiment was replicated in eight randomized blocks, and each plot was 35 feet long with 3 to 8 rows. The strengths and dosages of the DDT sprays and dusts and the number of applications were the maximum believed to be necessary for the seasonal control of the susceptible insect pests of the crops tested. Each crop was protected from insect damage so that the direct effect of DDT, exclusive of the influence of insect control, could be determined. Where DDT was ineffective against insect infestation, rotenone was applied to the entire experiment; where DDT was effective, check plots were dusted with one of the recommended insecticides known to be relatively harmless to the plants.

DDT caused no injury to Bountiful snap bean, Detroit Dark Red beet, Golden Acre cabbage, Hale's Best cantaloup, Abbott and Cobb cucumber, Ebenezer onion, Alaska and Thomas Laxton peas, Hubbard

winter squash, Katahdin and Sebago potatoes, and Purple Top White Globe turnip. DDT caused temporary foliage injury to Rutgers and Marglobe tomatoes, Irish Cobbler potato, Stringless Green Pod snap bean, and Fordhook lima bean, but did not affect the yields of these crops. DDT stunted the growth of Early Yellow Crookneck squash and reduced the yield.

Chemical analyses of the edible portions of the crops indicated that there was no absorption or translocation of DDT by the vegetables under the conditions of these experiments.

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