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UNITED STATES DEPARTMENT OF AGRICULTURE  
Agricultural Research Administration  
Bureau of Entomology and Plant Quarantine

RESULTS OF TESTS WITH DDT AGAINST FRUIT INSECTS IN 1944

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Because of the intense interest in DDT as an insecticide for the control of fruit insects, this brief summary of the results of work done by the Division of Fruit Insect Investigations has been prepared for early distribution, prior to publication of more detailed accounts of the work on individual insect pests. Acknowledgment is made of the cooperation of the Division of Insecticide Investigations, both at the Beltsville Research Laboratory and at field laboratories at Vincennes, Ind., Yakima, Wash., Moorestown, N. J., and Whittier, Calif.

EFFECT ON INSECT PESTS

Codling Moth

Results of small-scale replicated orchard experiments at several field laboratories indicate that DDT<sup>1/</sup> in strengths of 1/2 to 1 pound per 100 gallons of spray mixture is equal or superior to other materials that are being used for codling moth control, including lead arsenate, cryolite, and nicotine bentonite. Examples of these results follow.

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<sup>1/</sup> Throughout this paper the quantities indicated for DDT refer to the quantity or proportion of actual technical DDT, and not to the quantity of any of the various formulations.



Tests at Vincennes, Ind. (10 cover sprays)

| Treatment<br>(quantities per 100 gal.)                                                    | Worms per 100 apples |        |           |
|-------------------------------------------------------------------------------------------|----------------------|--------|-----------|
|                                                                                           | Rome                 | Turley | Ben Davis |
| Standard lead arsenate 3 to 4 lb.<br>(1/2 percent oil in 3 sprays)                        | 175                  | 98     | 166       |
| Nicotine bentonite <sup>2/</sup> (mostly tank-mixed):<br>2/3 to 1 pt. of nicotine sulfate |                      |        |           |
| Most effective treatment                                                                  | 32                   | 27     | 38        |
| Least effective treatment                                                                 | 77                   | 33     | 76        |
| DDT (in paste form):                                                                      |                      |        |           |
| 1/2 to 3/4 lb. (with bentonite and oil in 2 sprays)                                       | 18                   | -      | -         |
| 2/3 to 1 lb. (with oil in 2 sprays on Turley and<br>Ben Davis)                            | 22                   | 13     | 10        |
| 1 to 1 1/2 lb. (with bentonite and oil in 2 sprays)                                       | 2                    | -      | -         |

Tests at Kearneysville, W. Va. (4 first-brood cover sprays)

|                                                                                                        | Worms per 100 apples |
|--------------------------------------------------------------------------------------------------------|----------------------|
| Standard lead arsenate 3 lb.                                                                           | 101                  |
| Nicotine bentonite, tank mixed, 2/3 to 1 pt. of<br>nicotine sulfate (also 4 second-brood cover sprays) | 46                   |
| DDT:                                                                                                   |                      |
| 1 lb. (DuPont formulation, DDT 257)                                                                    | 48                   |
| 1 lb. plus pyrophyllite 1 lb. (micronized together)                                                    | 38                   |

Tests at Yakima, Wash. (6 cover sprays)

|                                        |      |
|----------------------------------------|------|
| Standard lead arsenate 3 lb.           | 16.6 |
| Nicotine bentonite (dry-mix 1:5) 3 lb. | 22.6 |
| Cryolite (90 percent) 3 lb.            | 14.4 |
| DDT 1/2 lb. plus pyrophyllite 1 lb.    | 11.4 |

<sup>2/</sup> Seven different nicotine bentonite programs were included in these tests. Detailed information on all of the programs is not given, but the range in results is indicated.



Tests at Poughkeepsie, N. Y. (6 cover sprays)

Worms per 100 apples

|                                                                                                             |       |
|-------------------------------------------------------------------------------------------------------------|-------|
| Standard lead arsenate 3 lb.                                                                                | 12.3  |
| Nicotine bentonite, tank-mixed, containing nicotine sulfate 1/2 pt. (4 sprays following 2 of lead arsenate) | 9.0   |
| DDT (micronized with equal weight of pyrophyllite)                                                          |       |
| 1 lb.                                                                                                       | 2.7   |
| 2 lb.                                                                                                       | 0.5   |
| Check(unsprayed)                                                                                            | 165.2 |

At Vincennes 4 ounces of DDT with half the usual concentration of lead arsenate or nicotine bentonite reduced the number of wormy apples to less than half of that resulting from standard lead arsenate or nicotine bentonite alone and as good results as DDT, 1 pound per 100 gallons, without any other insecticide. It is of interest to note that destructive increases in mite populations did not occur in the plots in which such low dosages of DDT were used, whereas they did occur in most plots in which higher ones were used.

In the Kearneysville experiments, the four applications of DDT gave almost perfect control of first-brood worms, and a continuation of the applications during the second-brood period presumably would have produced exceptionally clean fruit.

At Poughkeepsie a 5 percent DDT-pyrophyllite dust was more effective than a 20 percent lead arsenate or a phenothiazine dust, or 20 percent lead arsenate dusts combined with oil, nicotine bentonite, or lime, and gave better control than the grower's spray schedule, which included lead arsenate, fixed nicotine, and oil. Both here and at Vincennes DDT dusts were not so efficient as the sprays.

In a large-scale test in a heavily infested 8-acre block of apple trees at Vincennes, 10 cover sprays of DDT (prepared as a paste containing DDT 1 part (by weight), pyrophyllite 1 part, and water 2 parts), used at the rate of 1 pound per 100 gallons in 5 sprays and 3/4 pound per 100 in the others, were applied. On an average 23 worms per 100 apples were found in this area as compared with 68 in adjacent blocks receiving 11 cover and 2 top-off sprays of tank-mixed nicotine bentonite, the most effective spray mixture previously available for that locality.

Since residues of DDT on apples may later be found objectionable, exploratory work with residue removal is being undertaken. Preliminary tests at Vincennes have indicated that such residues may be difficult to remove by either brush machines or flotation-type washers. Soaps, oils, wetting agents, and strong alkaline solutions had little effect, and none removed as much as half the residue. Similar tests at Yakima confirmed



the results reported from Vincennes. A maximum of approximately 60 percent of the DDT spray residue was removed by using 2 percent of oil in water followed by a wash in a wetting agent to remove residual oil.

### Japanese Beetle

DDT has given outstanding control of adult Japanese beetles. In laboratory tests at Moorestown, N. J., as little as 1/16 pound of DDT in 100 gallons of water was as effective as 6 pounds of lead arsenate. In combination with most fungicides it was slightly less effective. In field tests, many of which were in cooperation with the New Jersey Agricultural Experiment Station, one to three sprays of DDT (micronized with equal parts of pyrophyllite, and with glue as a wetting agent) at the rate of 1 pound per 100 gallons gave almost complete control of the beetles on peaches, early apples, grapes, blueberries, and a miscellaneous group of ornamental and shade trees and shrubs. Applications after the first spray were necessary largely to protect new growth.

DDT applied in spray or in dust form has also been found very effective in soil treatments against the grubs of the Japanese beetle. Tests with 28 different soils, which have been in progress for more than a year, indicate that 25 pounds of DDT (in various formulations) per acre are more effective against third-instar larvae than 1,000 pounds of lead arsenate, and that the effectiveness of the DDT in the soil has not changed during the period of the tests. Large-scale tests in turf, with dosages of 25 and 35 pounds per acre, are now under way. Some of the soil tests, which resulted in plant injury, are discussed elsewhere. A more detailed report on this work will appear in the E series of the Bureau.

### Leafhoppers

Observations and the results of preliminary experiments indicate that DDT may control some species of leafhoppers effectively. At Yakima the DDT formulas used for control of the codling moth also appeared to control apple leafhoppers (chiefly Typhlocyba spp.). On August 28 the average number of leafhopper nymphs per 100 leaves was 0.6 on trees sprayed with DDT, 25.3 on trees sprayed with lead arsenate plus oil emulsion, and 74.3 on trees sprayed with nicotine bentonite. In codling moth field plots at Vincennes various DDT sprays gave complete control of several species of apple leafhoppers. Promising results in the control of the grape leafhopper were obtained in preliminary tests with DDT in Ohio, 1.5 pounds of DDT (dissolved in a mixture of benzene and kerosene, which was then emulsified) per 100 gallons, and in New Jersey (same formula as used in tests against Japanese beetle adults).

### Apple Aphids

At Vincennes, early in April 1944, it was noted that trees sprayed with DDT in several formulations in 1943 had very low or no aphid populations, although adjacent trees were heavily infested. In 1944 DDT was slow in eliminating aphids (all three species common on apple) already present, but they disappeared by mid-season. The apple-grain and the rosy apple aphids disappeared earlier from the trees treated with DDT than



they did from the untreated trees. In the fall aerial colonies of the woolly apple aphid were common on trees in lead arsenate plots, but absent from trees in DDT or nicotine plots.

At Yakima it has been noted that woolly aphids have become much more common in some apple trees sprayed with DDT (DDT 1 part plus pyrophyllite 2 parts) than in adjacent trees sprayed with lead arsenate. Here it is possible that DDT may be interfering with the activity of the Aphelinus parasite, which has been effective in holding the woolly aphid in check in the Pacific Northwest.

Tests made on the woolly apple aphid at Yakima in October, with DDT sprays that had been used for the codling moth during the summer, resulted in almost no control whatever. It was only by dissolving the DDT in a petroleum oil derivative, and using an emulsion of this solution with a wetting agent, that anything approaching satisfactory control of this aphid was obtained. It is recognized that the chief difficulty here may be the inability to wet the insects thoroughly.

#### Oriental Fruit Moth

Injury to peaches by the oriental fruit moth was reduced considerably in field plots sprayed with DDT (Japanese beetle formulation), 1 pound per 100 gallons, in an experiment conducted in cooperation with the New Jersey Agricultural Experiment Station. Two applications, one each just before the appearance of both second- and third-brood larvae, were more effective than one application made prior to appearance of the second brood. The DDT sprays reduced the activity of parasites, but did not eliminate them. At Moorestown DDT sprays were found to be much more toxic to adults of Macrocentrus ancylivorus Roh. than of the oriental fruit moth, and the residues were toxic to them for a much longer period.

#### Grape Berry Moth

In small-scale tests at Sandusky, Ohio, 1 1/2 pounds of DDT (in a mixture of benzene and kerosene that was emulsified) per 100 gallons did not kill the eggs of the grape berry moth on berries; it was about 50 percent effective 20 days after application in control of larvae trying to enter grape berries; and in a Latin-square field test it was more effective when used in three or four applications than lead arsenate used in four applications. In a large-block field test, however, one application of DDT did not hold up so well as one application of lead arsenate. In a field test of DDT (Japanese beetle formulation), 1 pound per 100 gallons, on Niagara grapes in New Jersey, 15.6 percent of the berries were injured in the DDT plot, and 41.7 percent in the lead arsenate plot, but on Jersey Muscat grapes DDT was no more effective than the standard lead arsenate treatment.

#### Rose Chafer

The results of a cage test at Sandusky indicate that DDT may control the rose chafer effectively. Grape foliage and clusters were sprayed on June 5 with DDT (same formulation as used on grape berry moth at Sandusky).



1 1/2 pounds per 100 gallons, and then placed in two cages; 25 beetles were introduced into each cage on June 5, 8, 13, and 17. All of the beetles were knocked down in less than 24 hours and were dead in less than 48 hours.

#### Scale Insects

In general, scale insects have been little affected by DDT. No benefit appeared to result from the addition of DDT to oil sprays against the Florida red scale and fig scale. The addition of DDT improved the immediate kill of Parlatoria chinensis Marlatt, but had no residual effect on crawlers. There was little or no immediate effect against the California red scale, but the residual value against crawlers was considerable in cool weather as compared with that in hot weather.

#### Plum Curculio

Against the plum curculio, DDT appears much less effective than lead arsenate. Tests at Beltsville with DDT-pyrophyllite (1:1), applied with various fungicides at the rate of 1 1/2 pounds of DDT per 100 gallons, indicated little control of curculio on apple and peach. At Fort Valley, Ga., 4 pounds of DDT (with wetting agent) per 100 gallons seemed to be about equal to the standard 2 pounds of lead arsenate for control of the curculio on peach.

#### Orchard Mites

At the dosages required for codling moth control, DDT apparently is not toxic to the Pacific mite, the European red mite, and the citrus red mite. In fact, the use of this chemical has in several cases caused an increase in mite population, apparently by eliminating or reducing the numbers of natural enemies of the mites. If DDT is used for the control of orchard insects, it is likely that some adjustment of spray programs will be necessary to provide for the control of mites in areas where they are present.

#### Other Insects

Preliminary laboratory or very limited field tests have been made with DDT in various formulations on many other insects. Favorable results have been obtained in the control of the pistol casebearer on apple, the grubs of the Asiatic garden beetle, an annual white grub, Cyclocephala borealis Arrow, in the soil, certain sucking bugs that cause distortion of peaches, the hickory shuckworm, the pecan weevil, chestnut weevils, the citrus thrips, the little fire ant on citrus trees in Florida, ants and saw-toothed beetles in raisin storages in California, the grape bud beetle (Glyptoscelis squamulata Crotch), and the grape rootworm.

With the apple maggot, the cherry fruitfly, the pecan nut casebearer, and newly hatched crawlers of the Comstock mealybug results have been promising enough to warrant further tests.



In small-scale field and laboratory tests at Poughkeepsie, pear psyllas were not controlled during the dormant season with 2 pounds of DDT plus 2 ounces of sodium lauryl sulfate per 100 gallons. Unfavorable results were also obtained in similar tests against the summer-brood nymphs with 1 1/2 pounds of DDT micronized with pyrophyllite (1:1) and with several other formulations.

#### EFFECT OF DDT ON TREES AND PLANTS

Most of the trees and plants on which DDT has been used have not shown evidence of injury. On some apple trees, however, there has been some yellowing and dropping of foliage, but an increase in mite abundance has been largely, if not wholly, responsible. In experiments with soil treatments for Japanese beetle grubs, 25 pounds of DDT per acre definitely retarded the growth of bush beans, lima beans, soybeans, hollyhock, onions, spinach, and tomatoes. Some of the bean leaves became yellow, and tomato plants were somewhat distorted. Higher strengths caused some growth retardation in beets, carrots, muskmelons, and potatoes. Tests are under way at Beltsville in which excessive quantities of DDT have been applied to the soil under apple and peach trees, to simulate the accumulation that might occur over a period of years if DDT should come into general use. Thus far no injury has become evident.

#### EFFECT OF DDT ON BENEFICIAL INSECTS

General observations have indicated that DDT is very toxic to many forms of insect life, and that its application to fruit trees brings down a tremendous number of beneficial insects. Cage tests have shown that DDT is extremely toxic to many hymenopterous parasites, including Macrocentrus ancylivorus of the oriental fruit moth and Pseudaphycus sp. of the Comstock mealybug. There are also numerous indications that DDT is fatal to many of the lady beetles that normally control aphids, mealybugs, and mites.

#### DDT MATERIALS AND FORMULATIONS

Either technical-grade DDT or DDT mixed with pyrophyllite in various proportions was used in most of the tests conducted during 1944. DDT-oil preparations were used in a few tests. The DDT dust preparations were ordinarily used as received or, when less concentrated mixtures were desired, were further diluted with pyrophyllite. The technical grade of DDT could not be used satisfactorily as received, and special treatment was necessary to process it for use as a powder, a paste, or as an emulsion. In some cases it was merely mixed with water containing a small amount of wetting agent. In others it was ground with water in a pebble mill; diluted with pyrophyllite, and micronized or ground dry or with water in a ball mill; diluted with pyrophyllite or kaolin and ground in a Mikropulverizer; or dissolved in a suitable solvent, such as mineral oil, kerosene, or benzene, and then emulsified.



Some of the formulations that were prepared and used were as follows (when not otherwise specified, proportions are by weight):

- (1) A micronized 1:1 mixture of DDT with pyrophyllite
- (2) A 40:60 DDT-water paste prepared by grinding in a pebble mill
- (3) A 1:2 DDT-pyrophyllite mixture ground in a ball mill
- (4) A 1:9 DDT-pyrophyllite mixture ground in a ball mill
- (5) A 1:1:2 DDT-pyrophyllite-water paste prepared by grinding in a ball mill
- (6) A 1:1 DDT-pyrophyllite mixture ground in a Mikropulverizer
- (7) A 1:1 DDT-kaolin mixture ground in a Mikropulverizer
- (8) 0.5 pound of DDT dissolved in 1 pint of benzene and emulsified with 0.5 ounce of B-1956 (a phthalic glycerol alkyl resin)
- (9) A stock emulsion prepared by dissolving 1.5 pounds of DDT in 58.8 ounces of benzene (tech.), adding 5.2 ounces of kerosene and 6.0 ounces of B-1956, shaking, and adding water to make 1 gallon
- (10) 1 pound of DDT dissolved in 1 quart of benzene or xylene and emulsified with casein and ammonia just prior to use
- (11) A 5 percent DDT-ethylene dichloride solution emulsified with IN-181-P (sodium alkyl sulfates, principally lauryl)

A satisfactory spray mixture was prepared as follows:

|                               |          |                       |
|-------------------------------|----------|-----------------------|
| DDT . . . . .                 | 1 lb. )  | ) micronized together |
| Pyrophyllite . . . . .        | 1 lb. )  |                       |
| Fish glue solution . . . . .  | 1 pt.    |                       |
| (1 lb. liquid glue per gal.)  |          |                       |
| Summer oil emulsion . . . . . | 1 qt.    |                       |
| Water to make . . . . .       | 100 gal. |                       |

The DDT-pyrophyllite mixture and the glue solution were placed in a pail and worked into a stiff paste with a small quantity of water. More water was then added, with constant stirring, until a thin paste was obtained. While the spray tank was being filled with water this paste was poured into it through a screen. When the tank was about three-fourths full, the summer oil was added and the tank was then filled to capacity.



At Moorestown the 10 percent DDT powder was not sufficiently free-flowing to be used in a Gandy spreader for soil treating. However, a suitable, but not altogether satisfactory, material was prepared by diluting the 10-percent material with sand until the DDT content was 2.5 percent. A suitable 10 percent DDT free-flowing mixture was prepared by adding 78 percent of talc and 2 percent of tricalcium phosphate to the 1:1 micronized DDT-pyrophyllite mixture.

Despite the work done on the preparation of DDT for use in sprays and as dusts, further improvement is needed in methods of formulation and application. The most immediate need is for a practical, wettable DDT preparation which can be used in the tank of standard orchard spray equipment without preliminary preparation. Experience appears to indicate that the material should be in powder form and contain the absolute minimum of diluents and wetting agents. Aqueous emulsions also appear to hold some promise.



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