May 1953

E-856

United States Department of Agriculture
Agricultural Research Administration
Bureau of Entomology and Plant QuarantineTESTS OF INSECTICIDES FOR CONTROL OF THE PICKLEWORM
AND ASSOCIATED INSECTS ON CUCUMBERS AND SQUASH--1948-51By W. J. Reid, Jr., and F. P. Cuthbert, Jr.
Division of Truck Crop and Garden Insect Investigations^{1/}

The pickleworm (Diaphania nitidalis (Stoll)) is a serious pest of cucurbit crops in the South Atlantic and Gulf States. It frequently causes considerable damage in adjoining States, and occasionally occurs as far west as Texas, Kansas, Missouri, and Iowa, and as far north as the tier of States extending from Illinois eastward to Connecticut, including New York. Summer squash is its favorite host, but it often severely damages cucumber and muskmelon. Occasionally young tender fruit of winter squash is attacked. The pickleworm is active throughout the winter in the extreme southern part of Florida, where its cultivated or native hosts are available continuously. From this and similar subtropical areas the insect gradually spreads northward each year, and usually appears later in the spring than most insects. Evidently it does not survive the winter as far north as the Carolinas.

The melonworm (Diaphania hyalinata (L.)), a species related to but less destructive and more easily controlled than the pickleworm, has about the same distribution in the United States. In addition, it has been reported from Arizona, New Mexico, and southern California, and adults have been taken in Canada. Apparently it also overwinters only in semitropical regions.

The banded cucumber beetle (Diabrotica balteata Lec.) and the spotted cucumber beetle (Diabrotica undecimpunctata howardi Barber) often injure young cucumber plants, and the striped cucumber beetle (Acalymma vittata (F.)) damages the plants and fruits. The melon aphid (Aphis gossypii Glov.) often causes serious damage to cucumbers.

Because of its habit of tunneling into the stalks, vines, buds, flowers, and fruit of cucurbits, the pickleworm has been difficult to control with the insecticides known prior to World War II. Studies conducted near Charleston, S. C., from 1930 through 1934 showed the need for more effective control measures. In 1948 these studies were resumed to determine the control value of some of the newly developed

^{1/} In cooperation with the South Carolina Agricultural Experiment Station.

insecticides. In addition, phytotoxicity experiments were made to learn the effect of the use of insecticides on the growth of the cucumber plants, as well as residue determinations and experiments on the effect of lindane on the odor and flavor of the fruit. All these studies are being continued, but the progress made through the 1951 season is reported herein.

REVIEW OF LITERATURE

Recommendations for control of the pickleworm prior to 1925 consisted chiefly of cultural practices. Quaintance (16, 17), Smith (19, 20), and Sullivan (21) advocated early planting, destruction of crop remnants, and use of squash as a trap crop in cucumber and cantaloup plantings. They considered insecticides of little value. Quaintance and Smith did advise the use of an arsenical spray to combat the melonworm. Cryolite or rotenone-containing materials were among the most effective insecticides in the discussions of the pickleworm published between 1937 and 1947 by White (23), Watts (22), Arant (3, 4, 5), and Fulton (11). Fulton reported that, except on very small cucumbers, cryolite residues were not excessive in North Carolina when the fruits were picked shortly before each dusting. He also obtained promising results with certain nicotine dusts. He considered the use of squash as a trap crop to be of doubtful value and the destruction of dead crop remnants of no benefit. He seems to have been the first to express the belief that the pickleworm overwinters only in semitropical regions, where a continuous source of food is available. Our findings in recent years substantiate this theory.

In studies made more recently in Virginia by Brooks and Anderson (6) and by Anderson and Hofmaster (2), BHC (benzene hexachloride), DDT, and TDE (DDD) proved effective against the pickleworm, but Brooks and Anderson reported that under certain conditions BHC caused severe injury to the new growth of cucumbers and cantaloups. Crowell and Morrison (8) found that all the chlorinated hydrocarbon insecticides seemed capable of inflicting injury to cucurbits. Alban and Keirns (1), Carruth and Howe (7), and Matthewman et al. (15), in tests in Ohio, New York, and Canada, respectively, found a purified grade of DDT having a setting point of about 103°C. to be less injurious to cucurbits than the technical grade.

The findings of Kelsheimer (13) in Florida in 1947 and 1948 and of Dupree and Beckham (9) in Georgia in 1951 regarding the relative effectiveness of lindane, parathion, purified DDT, and cryolite agree substantially with the data presented in this publication. Dupree and Beckman also noted an increase in melon aphids following the use of purified DDT, cryolite, and CS-708 (Dilan).

Considerable toxicity of the fungicide zineb to the pickleworm and the melonworm was observed in Florida in 1949 by Genung (12) and in South Carolina in 1950 by Reid (18). Genung stated in correspondence that he obtained similar results in Florida in 1950.

EARLY EXPERIMENTS

Nine experiments, consisting of field-plot comparisons of several insecticides in the control of the pickleworm and the melonworm on summer squash, were conducted by the senior author near Charleston, S. C., during the fall-crop seasons of 1930 through 1934. Cucumbers and muskmelons were added in 1934. From three to eight, usually four, replications of each insecticide were made on plots from 5 to 16 feet in width (1, 3, or 4 rows) and from 120 to 262 feet in length. The plant varieties used were White Bush, Yellow Crookneck, and Cocozelle squash, Early Fortune cucumbers, and Hale's Best muskmelons. The insecticides were applied with a bellows-type knapsack duster early in the morning in 1930-33 and in the early part of the night in 1934. The number of applications ranged from 5 to 12, and the dosage from 12 to 33 pounds per acre. An exception was a dosage of 54 pounds of a free-flowing lead arsenate-sulfur dust in one experiment. Applications usually were made every 3 or 4 days during the period of greatest insect abundance and every 7 to 10 days thereafter. Sometimes they were discontinued when fruiting began in order to avoid poisonous residues.

The results of these early experiments were based chiefly on yields of sound and wormy (pickleworm-infested) fruits, supplemented by pickleworm and melonworm survival counts in 1934.

The following insecticides were tested:

Lead arsenate, calcium arsenate, and potassium hexafluoroaluminate, undiluted and diluted with 5 parts of sulfur, hydrated lime, or a copper-lime fungicide.

Barium fluosilicate, diluted with 5 parts of hydrated lime in one test, and with 1 part of wheat flour and 4 parts of sulfur in another.

Cryolite (natural, containing 89 percent of sodium fluoaluminate), diluted with 1 part talc and 3 parts of sulfur.

Paris green, diluted with 4 1/2 parts each of hydrated lime and sulfur.

Derris powder, diluted with sulfur and either talc or kaolin, sulfur composing one-third of the mixture, which contained various strengths of rotenone; in one test derris was diluted with tobacco dust to contain 1 percent of rotenone.

Pyrethrum dust, two of unknown pyrethrin content and one diluted with tobacco dust to contain 0.1 percent of pyrethrin I.

Each of the insecticides gave adequate control of the melonworm. Counts made in 1934 indicated that a 1-percent rotenone dust gave 91 to 99 percent reduction, a 0.5-percent rotenone dust 74 to 95 percent, and an undiluted calcium arsenate dust 80 to 95 percent. The melonworm feeds almost exclusively on plant foliage and apparently is not difficult to combat with insecticides.

The pickleworm proved much more difficult to control than the melonworm. Each of the insecticides was of some value, but adequate control was seldom obtained when the insect was abundant, even though frequent applications were made. Yields of sound fruit obtained from untreated plants were relatively low, no sound or infested squash being produced by untreated plots in four experiments. Wormy fruits from untreated plants of the other experiments, during the peak of the pickleworm infestations, ranged from 45 to 74 percent of the squash produced. Applications made only during the prefruiting stage of squash growth were ineffective; 55 percent of the fruits were wormy when five applications of a lead arsenate-sulfur dust were made at that time.

Lead arsenate, potassium hexafluoroaluminate, and barium fluosilicate tended to be more effective against the pickleworm than calcium arsenate and paris green. Yields of sound squash obtained from plants receiving the most effective insecticides in 1932, potassium hexafluoroaluminate-sulfur and potassium hexafluoroaluminate-sulfur, were 274 and 246 bushels per acre, respectively, although 10 percent of the fruits were infested in each case. Untreated plants produced no squash.

In the one experiment in which it was used, a cryolite-talc-sulfur dust increased the yield of sound squash by 115 bushels per acre, and only 2 percent of the fruits were infested. In the same experiment a 1.5-percent rotenone dust increased the yield of sound squash by 137 bushels per acre, but 11 percent of the fruits were wormy. Untreated plants in this experiment produced no squash.

Dusts containing 0.5 and 1 percent of rotenone gave adequate control of a light pickleworm population, but were inadequate against moderate to heavy infestations when used alone and when preceded by applications of a lead arsenate-sulfur mixture before the fruit appeared. In spite of eight applications of these dusts, 73 and 59 percent of the fruits, respectively, became wormy in an experiment in which untreated plants produced no squash. Pyrethrum dusts also were ineffective when used alone and when preceded by a lead arsenate-sulfur dust.

Sulfur proved to be of considerable value as a fungicide and apparently of some value as an insecticide on squash. The yield of sound fruit was increased and the proportion of pickleworm-infested fruit reduced when sulfur was applied nine times in 1932. Forty-seven percent of the fruits were infested, as compared with 74 percent of those on untreated plants.

In 1933, the yield of sound squash was significantly higher when lead arsenate, calcium arsenate, and potassium hexafluoroaluminate

were diluted with sulfur than when used undiluted or mixed with hydrated lime or copper-lime.

In general, the early studies indicated that (1) the pickleworm is more difficult to control than the melonworm, (2) pickleworm mortality counts are impractical after the insects begin tunneling into the plants and fruits, (3) for adequate control the pickleworm must be killed before this tunneling begins, (4) undusted barrier rows and check plots serve as sources of infestation of surrounding plants, and (5) more effective control measures and insecticides involving residues less hazardous than used previously are needed.

PHYTOTOXICITY EXPERIMENTS

The effect of the periodic use of several new insecticides on the growth of three varieties of cucumbers was determined in the experiments conducted in the spring of 1948 and 1949. Practically no insects were present on cucumbers during these experiments, and all yield differences are considered to be due to the direct effect of the insecticides on the plants.

Each plot consisted of two rows 6 feet wide and 36.3 feet long. The plots were arranged in randomized blocks. Seven applications were made at weekly intervals in 1948 and eight in 1949, beginning about a week after the plants came up (when the second true leaves appeared) and ending the day of the third harvesting in 1948, and that of the first harvesting in 1949. The applications were made in the morning with rotary hand machines on wet to moist plants, with one or two trips per row. Dry plants were sprayed with water before being dusted. A cloth-covered hood with a plastic-cloth apron 8 or 10 feet long was often used to reduce insecticide drift.

In 1948 from 8 to 19 pounds per acre were used in the first four dustings and from 20 to 37 pounds thereafter. In 1949 the dosage ranged from 12 to 20 pounds for the first five dustings and from 20 to 26 pounds thereafter. Nine harvestings at 2- to 3-day intervals were made each season.

The yields of marketable cucumbers obtained during these experiments are summarized in table 1.

In 1948 a BHC dust severely bleached and stunted the plants of each variety from the outset, and reduced the yield of the Marketer variety by 35 percent and that of S. C. 5 (a mildew-resistant breeding line) by 69 percent.

In 1949 an impregnated 1-percent DDT dust made from a commercial dust that was stated to contain 10 percent of purified DDT (setting point 103°C.) and 23 percent of an aromatic petroleum-derivative solvent significantly affected cucumber yields. It caused chlorosis and stunting of the plants from the outset, the injury being severe after the third

application. Similar use of a dust containing only 2 percent of a commercial solvent (a mixture of di- and tri-methyl naphthalenes) on an outside row in the same cucumber planting apparently caused no injury to the plants. Yields of marketable Palmetto cucumbers, a recently developed mildew-resistant variety, were reduced by 64 percent and those of the S.C. 5 breeding line by 63 percent. The purified, but not impregnated, 3-percent DDT dust caused slight chlorosis in some S.C. 5 plants and moderate chlorosis in some Palmetto plants by the third application. This injury became less apparent as the plants grew, and there was no significant effect on yields. The 5-percent methoxychlor dust caused slight chlorosis in a few plants of each variety, but did not significantly affect the yields.

One percent gamma BHC dusts, prepared from concentrates of approximately 95-percent gamma content, caused no visible plant injury and did not significantly affect yields in either year. The commercial product used in 1948 had little odor when diluted to a 1-percent gamma dust; that used in 1949 had a slight odor. In 1948 plants of the Marketer variety getting the 1-percent gamma dust gave slightly higher yields than untreated plants; the reverse was true of the S.C. 5 breeding line. The yields of dusted plants of both S.C. 5 and Palmetto cucumbers tended to be lower than those of plants not receiving the gamma BHC dust in the spring of 1949, but the differences are not statistically significant. Lindane was used when it became available in the fall of 1949.

CONTROL EXPERIMENTS

Thirteen field-plot experiments designed to develop a program for the control of the pickleworm and associated insect pests on the fall crop of cucumbers were conducted each year from 1948 through 1951. Two experiments were conducted on squash, one each in 1950 and 1951.

Each insecticide treatment was used on four to six randomized-block replications of field plots consisting of one row of plants. The rows were 6 feet wide and $36 \frac{1}{3}$ feet long, or $\frac{1}{200}$ acre, in all but one test, in which they were 27 feet long, or $\frac{1}{269}$ acre. The dusts were applied in the same way as in the phytotoxicity tests. The sprays were applied (two or three trips per row) with a knapsack sprayer that maintained a fairly constant pressure.

Fungicide applications were made separately with power-driven machines, under the direction of a plant pathologist. Sprays were usually applied, but dusts were used when the field was too wet for the sprayer. Dosages ranged from 40 to 80 gallons per acre (depending on the size of the plants) of a mixture containing 1.3 pounds of ziram or zineb per 100 gallons of spray. Dusts containing 3.9 percent of ziram or zineb were applied at the rate of approximately 20 pounds per acre.

The fungicides were applied about once a week, beginning about 10 days after seeding and ending 2 to 3 weeks before completion of harvest.

The insecticide applications on cucumbers were made as shown in table 2.

Control During Early Stages of Plant Growth

Special efforts were made to find methods of evaluating the effectiveness of insecticides in pickleworm control before yield records could be obtained. Early-season control data were needed for comparison of the more toxic materials, which should be used only during the prefruiting period of plant growth because of residue hazards. In the early experiments examination of squash plants from which yield data were to be secured did not prove feasible, because the plants had to be destroyed to find the larvae that had tunneled into them. The problem was even more complicated with cucumbers, because it was difficult to separate the plants after the vines became entangled. Examination of surplus plants at the time of thinning and of the staminate flowers later were possibilities explored in the fall seasons of 1948 and 1949.

The numbers of surviving insects on surplus plants at thinning time provided an indication of the effect of the insecticides on pickleworms, melonworms, and melon aphids. The information was limited, however, by the small number of plants examined, the small size of the plants, the light infestation usually present at that time, and the few applications ordinarily made before thinning time. In spite of these factors, survival counts of the melonworm and melon aphid at this time seemed worth while.

The number of pickleworms and melonworms (the former comprising about 90 percent of the total) in the staminate flowers shortly before harvest was a reliable index to the effectiveness of the insecticides, being more closely correlated with yield data than counts made at thinning time. The pickleworm control in the flowers was usually higher than that obtained on the fruits. Control data based on flower examinations are limited, because ordinarily only small pickleworms feed in cucumber blossoms and many do not feed there at all. Squash flowers, however, are larger and larvae are able to complete development in them. Flower examinations made as near harvesttime as possible should prove valuable, particularly in work with squash, if yield data cannot be obtained.

Control During Fruiting Stages of Plant Growth

Results of the control experiments are based chiefly upon the percentage of wormy cucumber fruits of all sizes, the number of worm-free (sound) cucumbers of all sizes and quality, the number (and sometimes weight) of worm-free marketable fruits, and the degree of insecticide injury to the plants. Any cucumber that showed a pickleworm entrance hole was classed as wormy. From 7 to 11, usually 9 or 10, harvestings were made. Fruits from all plants on each plot were picked every 2 or 3 days. All cucumbers remaining on the plants were included in the last harvest. Where all marketable fruits were not weighed, the number required for a bushel was determined at least twice each season.

Yield data obtained from comparisons of the various insecticides are given in table 3, and those obtained from use of the more promising of these materials at various application intervals are shown in table 4.

Effects of certain insecticides on a moderate melon aphid infestation that occurred in plots of the 1951 pickleworm-control experiments were determined by picking 10 leaves at random from each plot and separating them into the following classes: Free (no aphids), slight (1 to 20 aphids), moderate (21-100 aphids), and heavy (more than 100 aphids). Numerical values were assigned to the various classes as follows: Free 0, slight 1, moderate 5, and heavy 20. The number of leaves occurring in each class was multiplied by the numerical value of the class, and the product was added to give the infestation rating of the plot (table 5).

In the following discussions the various insecticides are evaluated chiefly on the basis of the percent of the total number of fruits harvested that were wormy (pickleworm infested). Some consideration, however, is given to the relative number of all sound fruits produced, as well as to the yield of marketable cucumbers. In general, an insecticide will be regarded as having given adequate pickleworm control when the wormy fruits did not exceed about 1 or 2 percent of the total. Unless otherwise indicated, the proportions of constituents of the insecticide mixtures are on a weight basis.

Aldrin

A 2.5-percent aldrin dust was one of the materials proving most effective against the pickleworm (table 3). This insecticide did not provide quite adequate control of the heavy 1949 population, but it gave near-adequate protection against a moderate infestation in 1951. When used with zincb, it gave adequate control of a light infestation in 1950.

Aldrin was not tested so extensively as lindane. Aldrin was not compared directly with lindane in 1949, but apparently was inferior to it in that year. Aldrin was as effective as lindane in 1950 and 1951. There was no appreciable build-up of melon aphids on cucumbers treated

with aldrin in 1951 (table 5). This insecticide showed no phytotoxicity to cucumbers.

Allethrin

When applied directly on the insects in laboratory cage tests in 1950, a 0.5-percent allethrin dust proved toxic to third-instar pickleworms, but it was less effective against last-instar larvae, even when used at a heavy dosage. A 2-percent allethrin dust showed only moderate toxicity to last-instar pickleworms. The addition of 1 percent of piperonyl cyclonene and of compound 469 did not appreciably increase the toxicity of a 0.5-percent allethrin dust.

In field plots a 1-percent allethrin dust was of some value against a light pickleworm infestation in 1950, but was not of significant value when a moderate infestation prevailed in 1951 (table 3). Piperonyl butoxide, compound 469, and an activated nicotine did not appreciably increase the effectiveness of a 0.5-percent allethrin dust in 1951.

BHC

BHC caused serious injury to cucumbers in the spring of 1948 (table 1) and was not used in later tests. For tests with gamma BHC, see Lindane.

Chlordane

A 2-percent chlordane dust had no apparent ill effect on cucumbers in the spring of 1948 (table 1), but caused slight to moderate chlorosis of about one-third of the plants in the fall of that year. It was one of the least effective insecticides against the pickleworm in the fall of 1948 (table 3).

Cryolite

Cryolite gave an intermediate degree of control of the pickleworm. It provided adequate protection against the melonworm and cucumber beetles, but apparently increased melon aphid populations on cucumbers. This aphid was more abundant on cryolite-treated plants than on plants receiving any of the other materials in two experiments each in 1948 and 1949. In 1951 populations of this aphid were highly significantly greater on cryolite-treated cucumbers than on untreated plants (table 5).

A cryolite dust of 50-percent sodium fluoaluminate content gave near-adequate control of a moderate pickleworm population when applied every 5 or 7 days in 1948, but not when applied every 10 days (table 4). Weekly applications in 1949 did not give satisfactory protection against a heavy infestation. When accompanied by zineb, a 70-percent cryolite

dust gave satisfactory control of a light infestation in 1950 and near-adequate control of a moderate one in 1951 (tables 3 and 4).

Cryolite usually proved inferior to lindane and purified DDT and superior to methoxychlor. No phytotoxicity of cryolite to cucumber or squash plants was observed. Cryolite residues are discussed on page 17.

CS-674A, CS-645A, and CS-708

CS-674A proved superior to the similar material CS-645A in 1949, when used in 2-percent dusts against a heavy infestation of the pickleworm, but these materials and a mixture of them known as CS-708 did not give adequate control (table 3). CS-645A was more effective in a spray than in a dust. A 5-percent CS-708 dust gave adequate protection to cucumbers against a light infestation in 1950, but a 2-percent dust did not do so against a moderate infestation in 1951, being inferior to a 0.5-percent lindane dust. Plants receiving CS-708 in 1951 had a higher melon aphid infestation than untreated plants (table 5). The three materials showed no phytotoxicity to cucumbers.

DDT

In the fall of 1948 a dust containing 3 percent of a purified, or vine-safe, grade of DDT (setting point $103^{\circ}\text{C}.$) caused no apparent injury to cucumbers; a similar strength of technical DDT (setting point $90^{\circ}\text{C}.$) dust caused slight to moderate chlorosis of the foliage. Slight to moderate chlorosis of cucumbers, but no yield reduction, resulted from use of the purified grade in 1950. No difference in the degree of control of the pickleworm afforded by the technical and purified grades was indicated in the 1948 fall-season experiment (table 3).

The purified grade of DDT gave adequate protection to cucumbers against the melonworm and cucumber beetles and an intermediate degree of control of the pickleworm. Against the pickleworm DDT was usually inferior to lindane, tended to be superior to cryolite, and was superior to methoxychlor. The use of DDT apparently increased the melon aphid population on cucumbers in 1948 and in 1951 (table 5), but not so much as the use of cryolite.

A dust containing 3 percent of purified DDT gave near-adequate control of a moderate pickleworm population in 1948 when used every 5, 7, or 10 days (table 4), but not when applied every 7 to 14 days (table 3). Applications every 7 or 10 days did not give satisfactory protection against a heavy infestation in 1949 (table 4). When accompanied by zineb and applied every 5 to 10 days, this 3-percent dust gave adequate control of a light population in 1950 (table 4) and a similar 2-percent dust gave near-adequate control of a moderate infestation in 1951 (table 3).

Residues at harvest after the use of DDT on cucumbers are discussed on page 17.

Dieldrin

In laboratory cage tests in 1950 a 2.5-percent dieldrin dust gave complete kill of third-instar pickleworms, but only 30-percent kill of last instars. In a field experiment this dust gave complete control of a light pickleworm infestation in 1950 and adequate control of a moderate infestation in 1951, being among the most effective materials and as toxic as a 1-percent lindane dust (table 3). Dieldrin gave excellent control of the melon aphid in 1951 (table 5). It showed no phytotoxicity to cucumbers in 1950 and 1951.

A 1-percent endrin (the stereoisomer of dieldrin) dust was as effective against the pickleworm and the melon aphid as a 2.5-percent dieldrin dust in 1951 (tables 3 and 5). Endrin caused slight to moderate burning and chlorosis of cucumber foliage.

Heptachlor

A 0.24-percent heptachlor spray (2 pounds of a 50-percent wettable powder to 50 gallons) gave good control of a light pickleworm infestation in 1950, but a 2.5-percent dust did not prove very effective against a moderate infestation in 1951 (table 3). The dust apparently gave partial protection against the melon aphid (table 5). Heptachlor showed no phytotoxicity to cucumbers.

Lindane (or gamma BHC)

Lindane (or gamma BHC) was the most generally effective of the insecticides given extensive trials on cucumbers and squash. Good to excellent control of the pickleworm, as well as of the banded, spotted, and striped cucumber beetles, the melonworm, and the melon aphid, was obtained when a 1-percent dust of either material was applied every 7 to 10 days at about 20 pounds per acre (tables 3, 4, and 5). Emulsion sprays containing 0.025 to 0.058 percent of lindane applied to give 0.125 to 0.250 pound of lindane per acre and a suspension spray containing 0.06 percent applied at the rate of 0.25 pound of lindane per acre also gave good control of these insects. In 1950 and 1951 weekly applications of a 0.5-percent lindane dust gave good control of the pickleworm when accompanied by separate approximately weekly applications of zineb.

Gamma BHC and lindane provided satisfactory insect control on several thousand acres of fall-crop cucumbers grown in the vicinity of Charleston, S. C., between 1948 and 1951.

LIBRARY
STATE PLANT BOARD

No phytotoxicity of lindane to cucumber and squash was observed, except that in 1950 the emulsion spray caused a slight chlorosis of small cucumber plants. These plants were not injured by later applications, and their yields apparently were not affected. A 1-percent lindane dust applied every 5 days sometimes caused slight to moderate injury, such as might result from excessive deposits of any dust on cucumber foliage.

Preliminary taste tests were made at three locations between 1948 and 1950 by about 83 persons, including men, women, and children, in efforts to determine effects of lindane and gamma BHC on the palatability of cucumber fruits. Experienced taste panels were not involved in the studies. Approximately 118 comparisons were made of lots of one to three cucumbers from lindane-treated and untreated field plots. Practically all the treated samples came from plants that received several applications of either a 1-percent gamma dust or a spray containing 1 pound of a wettable 25-percent gamma powder to each 100 gallons of water, the last application usually being made the day the samples were harvested. Off-flavor or off-odor of one or more of the fruits in the treated lots was reported in 18 percent of the comparisons, but only a few of them were said to be objectionable. Only two persons are known to have distinguished between all treated and untreated fruits. One of these persons has had considerable taste-panel experience. He stated that the off-flavor probably would not be noticed by the average person.

Lindane has been used extensively in recent years on commercial plantings of fresh market cucumbers in the vicinity of Charleston, S. C. No complaints of an objectionable odor or taste of the fruits have come to our attention. We understand that similar conditions have prevailed in other southeastern States. It is possible that off-flavor following the use of lindane may be more pronounced when the cucumbers are picked when they are small, as usually is done for pickling.

Since potatoes grown in soil treated with lindane may have a musty odor and flavor, as reported by Kirkpatrick et. al. (14), tests were made to determine whether the application of lindane to cucumber plantings would contaminate the soil sufficiently to affect the flavor of subsequent crops of potatoes. In 1951 five varieties of potatoes--Pontiac, Bliss Triumph, Irish Cobbler, Sebago, and Cherokee--were grown in plots of Dupont very fine sandy loam soil in which cucumbers had been grown in the fall of 1950. The pickleworm had been adequately controlled on the cucumbers by a total of 1 1/4 pounds of lindane per acre in eight weekly applications. For checks the same varieties of potatoes were grown within about 50 yards in a similar field in which lindane had never been used. Samples of the potatoes were tested by an experienced taste panel in the Bureau of Human Nutrition and Home Economics. The Irish Cobbler and Pontiac varieties from the treated plots had significantly poorer flavors than the same varieties from the field where lindane had never been used. The off-flavor was characterized as musty and characteristic of BHC, but in no sample tested was it intense or extremely

undesirable. The results with Bliss Triumph were not clear-cut but showed a similar trend, whereas there was no significant off-flavor in the other two varieties.

Insecticide residues on cucumber fruits following field applications of lindane and gamma BHC are discussed on page 17.

Methoxychlor

Methoxychlor proved to be one of the least effective materials against the pickleworm. Inadequate control resulted from the use of a 5-percent dust in 1948 (table 3) and in 1949 (table 4), a 2.5-percent impregnated dust in 1949 (table 3), a 10-percent dust in 1950 and 1951 (table 3), a 0.181-percent suspension spray in 1949, and a 0.189-percent emulsion spray in 1949 (table 3). Methoxychlor was inferior to lindane in every comparison and usually proved inferior to cryolite. Methoxychlor was of considerable value in the control of the melonworm in 1948 and 1949 (data not shown in tables). This material did not reduce the melon aphid infestation in 1951 (table 5), but on methoxychlor-treated plants the aphid population was lower than on plants receiving several other insecticides and was no higher than that on untreated plants. Methoxychlor caused slight to moderate chlorosis of cucumber plants, but this injury did not appreciably affect yields. Methoxychlor residues are discussed on page 17.

Nicotine

Nicotine was used as an additive to control the melon aphid and to increase the degree of pickleworm control given by another insecticide. A cryolite-nicotine dust held the melon aphid in check in 1948 and 1949, but there was an increase in the infestation when cryolite was used alone. Nicotine was of significant value against the pickleworm when used with cryolite in 1949 and tended to be so in 1950 (table 3). However, it was of no significant value against the pickleworm when used with cryolite or rotenone in 1948 (table 3), or when added to rotenone, sabadilla, or pyrethrum in 1950 or to sabadilla and allethrin in 1951 (table 3).

Dusts containing 1 percent of nicotine and 4 percent of either polyethylene glycol (600) monolaurate or bis(p-chlorophenyl) sulfide^{2/} were ineffective against the pickleworm on squash and on cucumbers (table 3) in 1951. Cucumber plants receiving these dusts had significantly higher melon aphid infestations than did untreated plants (table 5). The first mixture caused slight injury, and the second mixture caused severe injury and a reduction in yield. A dust containing 0.5 percent of

^{2/} These mixtures were supplied by the Bureau of Agricultural and Industrial Chemistry.

nicotine, 2 percent of polyethylene glycol (600) monolaurate and 20 percent of sabadilla did not give adequate control of the pickleworm in 1951 (table 3).

Parathion

Parathion was among the most effective materials tested, but was not given such extensive trials as lindane, DDT, cryolite, and methoxychlor. It gave good control of the melonworm and the melon aphid in 1948, and of the melon aphid in 1951 (table 5). Parathion was less effective than gamma BHC and lindane against the pickleworm, when used as 1-percent dusts (tables 3 and 4). A 0.5-percent parathion dust was inferior to a 0.5-percent lindane dust against the pickleworm in 1951 (table 3). The residual effect of parathion against this insect did not appear to be so lasting as that of lindane, cryolite, and DDT. Five applications of a 1-percent parathion dust at intervals of 7 to 8 days gave almost adequate protection to cucumbers against a heavy pickleworm infestation in 1949; four applications of a 0.045-percent parathion suspension gave excellent control that season (table 3). Similar use of a 1-percent dust provided adequate control of the lighter infestations in plantings being treated with zineb in 1950 (table 4) and 1951 (table 3). This insecticide showed no phytotoxicity to cucumbers even though in 1950 as many as seven applications of a 1-percent dust were made, beginning when the plants had only one to three true leaves.

A spray containing 0.028 percent of Metacide, a product containing methyl parathion and parathion, was among the least effective materials used against the pickleworm in experiment 1 of 1950, and did not provide adequate control of this insect (table 3).

Pyrethrum

Pyrethrum dusts showed a high degree of toxicity to pickleworms in laboratory cage tests. An impregnated 0.4-percent pyrethrins dust gave complete kill of all stages of the pickleworm in 1950. An impregnated 0.2-percent pyrethrins dust killed 90 percent of fifth-instar larvae. A 0.1-percent dust killed all fourth instars, but only 15 percent of the fifth instars. A 0.3-percent pyrethrins dust made directly from pyrethrum powder was about as effective as the 0.1-percent impregnated dust. Addition of 1 percent of piperonyl butoxide slightly increased the effectiveness of the impregnated 0.1-percent pyrethrins dust.

When used under field conditions, pyrethrum dusts did not give adequate protection of cucumbers against moderate to heavy infestations of the pickleworm (table 3), even when the pyrethrins content was as high as 1 percent. Piperonyl cyclonene, piperonyl butoxide, n-propyl isome, and compound 469 did not significantly increase the effectiveness of pyrethrum (table 3).

Q-137

In laboratory cage tests in 1950, average and heavy dosages of a dust containing 3 percent of Q-137 showed only moderate toxicity to third- and fourth-instar pickleworms. A 5-percent dust was one of the least effective insecticides used on field plots in experiment 1 of 1950, but gave almost adequate control of the light pickleworm infestation (table 3). Q-137 showed no phytotoxicity to cucumbers.

Rotenone

Insecticides containing rotenone showed little toxicity to fifth-instar pickleworms in laboratory cage tests. A 1-percent rotenone dust killed only 20 percent of these larvae; a 2-percent dust killed 70 percent. The effectiveness of a 1-percent rotenone dust was not appreciably increased by addition of 1 percent of either piperonyl butoxide or compound 469.

One-percent rotenone dusts did not give adequate control of the pickleworm in field tests (table 3), even though in 1951 they were preceded by lindane and accompanied by zineb. During the fruiting period of cucumber growth in 1950, populations were too low for the value of 1.5- and 2-percent rotenone dusts to be determined. Addition of piperonyl cyclonene, n-propyl isome, nicotine, or mineral oil did not significantly increase the toxicity of a 1-percent rotenone dust in 1948 and 1949 (table 3). A dust containing 0.15 percent of pyrethrins and 0.5 percent of rotenone was ineffective on cucumbers in 1948.

Ryania

A dust containing 40 percent of ryania did not give adequate control of the pickleworm in 1948 and 1949 (table 3).

Sabadilla

A 20-percent sabadilla dust did not provide adequate protection against the pickleworm, but this dust tended to be slightly more effective than rotenone, pyrethrum, allethrin, and ryania dusts (table 3). Addition of 0.5 percent of nicotine plus 2 percent of polyethylene glycol (600) monolaurate did not significantly increase its effectiveness in 1951. In the 1950 planting the pickleworm infestation was too low for the value of a 25-percent sabadilla dust, with and without piperonyl butoxide and nicotine, to be determined.

TDE

A 3-percent TDE dust was one of the least effective materials used against the pickleworm in experiment 1 of 1950 (table 3). It was inferior to a 0.5-percent lindane dust, and caused moderate chlorosis of cucumber foliage.

Tetraisopropyl Pyrophosphate

A 1-percent tetraisopropyl pyrophosphate dust was of no apparent value against the pickleworm in experiment 1 of 1949 (table 3), and gave only 53-percent reduction of the melonworm in that year. The material caused no noticeable plant injury.

Effect of Zineb on the Pickleworm

During the 1950 studies considerable evidence was obtained to substantiate the observations of Genung (12) that the fungicide zineb is moderately toxic to the pickleworm. The unusually low pickleworm infestation on cucumbers in the Charleston, S.C., area in the fall of that year was attributed at least partly to the extensive use, for the first time, of zineb for disease control. Additional evidence of the toxicity of zineb to the pickleworm was obtained by several laboratory cage tests and a small-scale field-plot experiment on squash (Reid 18).

In experiment 3 of 1951 (table 3) two 4-percent zineb dusts prepared from different commercial brands of that fungicide significantly reduced the number of pickleworm-infested cucumbers, but did not give adequate protection. Both dusts caused slight chlorosis of the foliage and also a significant increase in the melon aphid population (table 5).

The partial control of the pickleworm with zineb gave promise in 1951 of making possible adequate control of that insect with lower dosages of lindane than previously used, thereby reducing the danger of poisonous residue, off-flavor, and soil contamination. Five applications of a 0.5-percent lindane dust gave excellent protection to cucumbers against a moderate pickleworm infestation in experiment 1 of 1951 (table 3), when accompanied by weekly applications of zineb. In another planting receiving similar applications of zineb, a 1-percent lindane dust applied a week before and at the time the first fruits appeared gave almost complete protection through the seventh of 12 harvestings of cucumbers. A dust containing 0.25 percent of lindane and 0.1 percent of pyrethrins applied shortly after the seventh harvesting gave almost adequate protection thereafter to this planting (experiment 2 of 1951, table 3). Separate applications of pyrethrum, sabadilla, and rotenone were of very little value.

RESIDUE STUDIES

Representative samples of cucumbers from plants treated with certain insecticides shortly before or during the fruiting period, or at both times, were collected in 1948 and 1949 by W. J. Barbour, resident inspector of the Food and Drug Administration, and sent to the Atlanta, Ga., office for residue determinations. Similar samples were furnished the Division of Insecticide Investigations of this Bureau in 1950. The cucumbers were of slicing size, averaging about 2 1/4 inches in diameter and 0.65 pound in weight. Some of the 1948 samples were run through a brushing and waxing machine, and some of the 1949 samples through a more elaborate washing, waxing, and polishing machine. The treatments of the various samples and the findings of the chemists are shown in table 6.

The quantity of residue from the different insecticides and from different samples of certain insecticides varied considerably. The only residues of appreciable quantity were those that followed the use of gamma BHC in the fall of 1948 during the fruiting period, and of cryolite in the spring of 1949. Similar applications of gamma BHC in the spring of 1949 and of lindane in the falls of 1949 and 1950 apparently resulted in little or no residue at time of harvest. Cryolite residues were rather variable and sometimes as high as 82 p.p.m. of fluorine. It is not understood why plants that received the last cryolite application on May 23, 1949, before the fruits appeared on the plants, produced fruits showing 9.6 p.p.m. of fluorine. A control program in which lindane was used during the prefruiting period and cryolite thereafter resulted in residues of 0.6 p.p.m. of gamma BHC and 2 p.p.m. of fluorine. The fluorine residue was reduced to 0.2 p.p.m. by washing and waxing of the fruits. DDT, parathion, and methoxychlor residues were low, even when these materials were applied on the day of harvest. The lindane and cryolite residues were reduced as much as 80 to 90 percent by commercial brushing (or washing) and waxing machines. These machines may not have reduced the residues to safe levels, however. Similar findings for cryolite have been reported by Fulton (11).

SUMMARY

The pickleworm (Diaphania nitidalis (Stoll)) and the melonworm (Diaphania hyalinata (L.)) are serious pests of fall crops of squash and cucumber in the South Atlantic and Gulf States. They also frequently cause damage in adjoining States and occasionally as far north as Illinois and Connecticut. These insects spread northward each spring and summer from semitropical areas. The melon aphid (Aphis gossypii Glov.) and several species of cucumber beetles cause damage to cucurbit crops at times.

Experiments conducted between 1930 and 1934 showed that adequate protection against the melonworm and a fair degree of control of the pickleworm could be obtained by frequent applications of lead arsenate, potassium hexafluoroaluminate, cryolite, or barium fluosilicate. Calcium arsenate, paris green, pyrethrum, and rotenone usually were less effective against the pickleworm. Sulfur proved to be of considerable value as a fungicide and of some value as an insecticide in the dust mixtures.

In 1948 laboratory cage and field-plot experiments were undertaken to develop more effective and safer measures for the control of the pickleworm and associated insects. Lindane was the most effective material given extensive trial. A 1-percent lindane dust applied weekly at the rate of about 20 pounds per acre, or sprays providing a comparable dosage, gave excellent control of all insects present on cucumbers and squash. There were indications, however, that the use of lindane during the fruiting period may impart a slight off-flavor or off-odor to cucumbers, and that certain varieties of Irish potatoes may be similarly affected when that crop immediately follows lindane-treated cucumbers.

Parathion, although tested less extensively than lindane, proved only slightly less effective against the pickleworm and was as toxic as lindane to the melon aphid and the other insects. A purified grade of DDT usually proved inferior to lindane but superior to cryolite against the pickleworm. However, a marked increase in the melon aphid population often followed the use of DDT and cryolite. Aldrin, dieldrin, and endrin showed considerable promise against both insects in limited trials.

Insecticides that proved less effective against the pickleworm were chlordane, methoxychlor, CS-674A, CS-645A, CS-708, tetraisopropyl pyrophosphate, TDE, Q-137, heptachlor, Metacide, and nicotine plus either bis(p-chlorophenyl) sulfide or polyethylene glycol (600) mono-laurate.

Dusts containing rotenone, pyrethrum, sabadilla, allethrin, and ryania did not provide adequate protection to cucumber fruits against moderate to heavy infestations of the pickleworm, even when supplemented with several additives.

Zineb was found to have some toxicity to the pickleworm. Weekly use of this material for disease control did not give adequate protection to cucumbers and squash against that insect, but evidently made it possible for control to be obtained more easily with lindane and certain other insecticides.

Several of the insecticides were found to be phytotoxic to cucumbers. BHC, nicotine with bis(p-chlorophenyl) sulfide, and dusts impregnated with both technical and purified DDT caused severe chlorosis of the plants and greatly reduced the yield of fruits. Less serious injury to the plants and no apparent effect on yields resulted from use of ordinary

DDT dusts (both grades) and of TDE, methoxychlor, chlordane, endrin, zineb, and nicotine plus polyethylene glycol (600) monolaurate.

Insecticide residues as high as 12.2 and 82 p.p.m., respectively, were found on cucumbers when gamma BHC and cryolite were applied weekly until the day of harvest. These residues were reduced to 7.7 and 16.2 p.p.m., by a commercial brushing or washing machine. Residues that followed similar use of lindane, purified DDT, parathion, and methoxychlor were not more than 1.6 p.p.m.

LITERATURE CITED

- (1) Alban, E. K., and Keirns, V. E.
1948. The effect of rotenone, commercial, and aerosol grade DDT dusts on the total yield, grade, and maturity of seven cucurbit varieties. Amer. Soc. Hort. Sci. Proc. 51: 448-452.
- (2) Anderson, Lauren D., and Hofmaster, Richard N.
1948. Control of pickleworms on cucumbers and cantaloupes. Jour. Econ. Ent. 41: 334-335.
- (3) Arant, F. S.
1940. A progress report on the use of rotenone dusts for the control of the pickleworm and the melonworm in Alabama. Jour. Econ. Ent. 33: 840-843.
- (4) _____
1941. Rate of application of derris-talc dusts for pickleworm control. Jour. Econ. Ent. 34: 520-521.
- (5) _____
1942. Effectiveness of derris and cube in pickleworm control. Jour. Econ. Ent. 35: 870-872.
- (6) Brooks, James W., and Anderson, Lauren D.
1947. Toxicity tests of some new insecticides. Jour. Econ. Ent. 40: 220-228.
- (7) Carruth, L. A., and Howe, W. L.
1948. Factors affecting use and phytotoxicity of DDT and other insecticides for squash borer control. Jour. Econ. Ent. 41: 352-355.
- (8) Crowell, H. H., and Morrison, H. E.
1950. The phytotoxicity to cucurbits of some new insecticides. Jour. Econ. Ent. 43: 14-16.

- (9) Dupree, Minter, and Beckham, C. M.
1952. Progress report of insecticide tests for control of pickle-worm on cucurbits. Ga. Agr. Expt. Sta., Mimeo Series 39, 8 pp.
- (10) Fulton, B. B.
1947. Biology and control of the pickleworm. N.C. Agr. Expt. Sta. Tech. Bul. 85, 27 pp.
- (11) Genung, William G.
1949. Dithane dust indicates effective control of melon worm and pickle worm. Fla. State Hort. Soc. Proc. 62: 130-132.
- (12) Kelsheimer, E. G.
1949. Control of insect pests of cucumber and squash. Fla. Agr. Expt. Sta. Bul. 465, 15 pp.
- (13) Kirkpatrick, Mary E., Mountjoy, Beatrice M., Albright, Linda C., Poos, Fred W., and Weigel, Charles A.
1951. Flavor and odor of cooked potatoes as affected by use of lindane and benzene hexachloride as insecticides. Amer. Potato Jour. 28: 792-799.
- (14) Matthewman, W. G., Harcourt, D. G., Cass, L. M., and Friend, W. G.
1950. The varietal reactions of cucumbers to DDT and methoxy-chlor dust. Canad. Ent. 82: 102-111.
- (15) Quaintance, A. L.
1899. Some important insect enemies of cucurbits. Ga. Expt. Sta. Bul. 45, pp. 36-41.
- (16) _____
1901. The pickle-worm. Ga. Agr. Expt. Sta. Bul. 54, 94 pp.
- (17) Reid, W. J., Jr.
1951. Zinc ethylene bisdithiocarbamate toxic to pickleworm and melonworm. Jour. Econ. Ent. 44: 817-818.
- (18) Smith, R. I.
1910. Insect enemies of cantaloupes, cucumbers and related plants. N. C. Agr. Expt. Sta. Bul. 205, pp. 29-35.
- (19) _____
1911. Two important cantaloupe pests. N. C. Agr. Expt. Sta. Bul. 214, pp. 105-126.

(20) Sullivan, K. C.

1924. The pickleworm and its control. Mo. Agr. Expt. Sta.
Cir. 122, 4 pp.

(21) Watts, J. G.

1939. Insect control investigations - The pickleworm. S. C.
Agr. Expt Sta. A. R. 521, pp. 189-193.

(22) White, W. H.

1937. Recommendations for the control of insects attacking
certain vegetables, small fruits, and tobacco. U.S.
Bur. Ent. and Plant Quar. E-376, 14 pp.

Table 1. --Effect of various insecticide dusts on the marketable yields of three varieties of cucumbers, 1948-49

Insecticide (figures indicate percents)	Average dosage per acre	Marketer fruits			S.C. 5 fruits			Palmetto fruits		
		On treated areas	Per acre	Number	Bushels	On treated areas	Per acre	Number	Bushels	
										Pounds
Spring 1948, 7 applications										
BHC (technical), gamma 1	17	301	271	135	133	-	-	-	-	-
Gamma BHC 1	17	434	412	390	410	-	-	-	-	-
Chlordane 2	21	437	455	424	433	-	-	-	-	-
Cryolite 50 $\frac{1}{2}$	18	418	411	397	405	-	-	-	-	-
DDT 1	18	437	415	363	361	-	-	-	-	-
Methoxychlor 5	19	495	467	404	402	-	-	-	-	-
Parathion 1	21	429	402	368	388	-	-	-	-	-
Untreated	0	421	415	404	425	-	-	-	-	-
Least significant difference at odds of 19:1 - - 115.5 96.6 104.5 105.0 - -										
99:1 - - 158.0 132.4 143.0 143.8 - -										
Spring 1949, 8 applications										
Gamma BHC 1	19	-	-	611	382	422	266	-	-	-
Cryolite 50 $\frac{1}{2}$	19	-	-	725	453	484	313	-	-	-
DDT 3 (purified)	18	-	-	654	409	524	339	-	-	-
1 (purified and impregnated)	18	-	-	267	162	171	109	-	-	-
Methoxychlor 5	19	-	-	657	410	442	284	-	-	-
Parathion 1	18	-	-	651	407	435	279	-	-	-
Untreated	0	-	-	713	438	470	301	-	-	-
Least significant difference at odds of 19:1 - - - - - 192.2 -										
99:1 - - - - - 263.3 -										

^{1/2} Percentage given with cryolite indicate the sodium fluoaluminate content.

Table 2.--Dusting and spraying schedule on cucumbers, 1948-51

Experiment No.	General applications ^{1/}		Applications of test insecticides	
	Insecticide	Date	Beginning	Ending
			<u>Experiments in 1948 (plots seeded on August 16)</u>	
1	None	-	Aug. 27 (11 days after seeding)	Sept. 30 (when first small fruits appeared)
2	None	-	26 (10 days after seeding)	Oct. 21 (2 weeks before last harvest)
3	Gamma BHC 1% dust	Aug. 26, Sept. 1, 8, 14, 21	Oct. 6 (time of first harvest)	Do.
			<u>Experiments in 1949 (plots seeded on August 12)</u>	
1	Lindane 1% dust	Aug. 22, 30	Sept. 7 (time plants were thinned)	Oct. 7 Do.
2	None	-	Aug. 22 (10 days after seeding)	14 (1 week before last harvest)
3	None	-	Sept. 13 (just before first fruits appeared)	6 (8 days before last harvest)
4	Lindane 1% dust	Aug. 22, 30, Sept. 6, 15	23 (1 week before first harvest)	12 (1 week before last harvest)
			<u>Experiments in 1950 (plots seeded on August 16)</u>	
1	Lindane 1% dust	Aug. 30	Sept. 13 (1 week before first pistillate flowers opened)	Oct. 5 (3 weeks before last harvest)
2	None	-	Aug. 28 (12 days after seeding)	10 (2 weeks before last harvest)
3	Lindane 1% dust	Aug. 30, Sept. 8, 15, 22	Sept. 29 (day of first harvest)	6 (3 weeks before last harvest)
			<u>Experiments in 1951 (plots seeded on August 21)</u>	
1	Lindane 0.1 lb. per acre as a suspension spray	Aug. 20, Sept. 6	Sept. 24 (just before first pistillate flowers opened)	Oct. 24 (2 weeks before last harvest)
2	Lindane 0.1 lb. per acre as a suspension spray	Aug. 30, Sept. 6	Oct. 24 (1 application, middle of harvest period)	-
3	Lindane 1% dust	Sept. 25, Oct. 2	-	-
	Lindane 0.1 lb. per acre as a suspension spray	Aug. 30, Sept. 6	Sept. 25 (just before first pistillate flowers opened)	18 (3 weeks before last harvest)

^{1/} Ziram was used as a fungicide in 1948 and 1949 and in experiment 3 in 1951, and zineb was used in 1950 and 1951.

Table 3. --Control of the pickleworm on fall cucumbers with various insecticides, 1948-51. All insecticides applied as dusts except where sprays are indicated.

Insecticide (figures indicate percent)	Average dosage per acre	All cucumbers harvested		Marketable cucumbers per acre
		Sound	Wormy	

Number Percent Bushels					
1948, Experiment 1 (4 applications at 7- to 14-day intervals)					
Gamma BHC 1	19 pounds	55	10	24	
0.5	18	37	24	13	
Parathion 1	18	36	18	13	
DDT 3	17	24	56	8	
3 (purified)	18	22	60	8	
1 plus pyrethrins 0.12 (both impregnated)	20	7	30	2	
1 (impregnated)	19	20	31	7	
1	20	16	67	5	
Cryolite 50 plus nicotine 1	18	23	51	9	
50	20	19	56	7	
Methoxychlor 5	19	15	53	5	
Rotenone 1	17	13	65	4	
Chlordane 2	22	9	71	3	
Least significant difference at odds of 19:1		-----		44.5	-
99:1		-----		59.1	-
1948, Experiment 3 (3 applications at 7-day intervals)					
Gamma BHC 1	25	394	4	69	
Sabadilla seed powder 20	27	306	22	56	
Ryania powder 40	27	320	25	63	
Pyrethrins 0.3	31	309	28	65	
.15 plus rotenone 0.5	30	313	30	63	
Rotenone 1 plus piperonyl cyclonene 0.5	26	277	35	54	
1 plus nicotine 1	29	283	36	51	
1 plus oil $\frac{1}{2}$	26	287	36	52	
1 plus oil $\frac{1}{1}$	26	270	38	55	
1	28	230	43	41	
0.25 plus piperonyl cyclonene 0.5	29	236	43	44	
.5 plus piperonyl cyclonene 0.5	30	265	43	54	
Untreated	-	230	48	33	
Least significant difference at odds of 19:1		-----		17.0	-
99:1		-----		22.6	-

$\frac{1}{2}$ Highly refined, paraffin-base mineral oil of approximately 75 seconds Saybolt viscosity at 100° F., unsulfonated residue approximately 90 percent.

Table 3.--Continued

Insecticide (figures indicate percent)	Average dosage per acre	All cucumbers harvested		Marketable cucumbers per acre
		Sound	Wormy	
		Number	Percent	Bushels
1949, Experiment 1 (5 applications at 7- to 8-day intervals)				
Parathion 1	23 pounds	473	10	134
Aldrin 2.5	22	503	15	151
CS-708 3	23	380	32	119
CS-674A 2	22	354	34	104
Cryolite 50 plus nicotine 2 and lime 5	21	297	36	97
50	22	224	47	80
CS-645A 2	23	187	52	66
Methoxychlor 2.5 (impregnated)	22	130	64	46
Tetraisopropyl pyrophosphate 1	22	52	77	19
Untreated	-	45	74	17
Least significant difference at odds of 19:1 - - - - -		78.7	9.7	34.1
99:1 - - - - -		105.1	13.0	45.6
1949, Experiment 3 (4 applications at 6- to 10-day intervals)				
Parathion 0.045 (suspension spray)	66 gallons	246	0.8	107
CS-645A 0.094 (emulsion spray)	66	218	4	96
Methoxychlor 0.181 (suspension spray)	66	48	75	16
.189 (emulsion spray)	66	34	77	14
Untreated		15	89	6
Least significant difference at odds of 19:1 - - - - -		93.5	27.9	60.5
99:1 - - - - -		131.1	39.2	84.9
Lindane 0.047 (emulsion spray)	66	233	2	194
1949, Experiment 4 (4 applications at 6- to 7-day intervals)				
Sabadilla seed powder 20	26 pounds	349	34	125
Pyrethrins 1	27	406	35	141
0.3 plus piperonyl cyclonene 1	27	313	44	112
.3 plus <u>n</u> -propyl isome 1	26	295	44	112
.3	27	292	46	103
Rotenone 1 plus piperonyl cyclonene 1	25	332	45	117
1 plus <u>n</u> -propyl isome 1	25	285	46	96
1	25	322	44	116
Ryania 40	26	275	44	103
Untreated	-	182	56	69
Least significant difference at odds of 19:1 - - - - -		9.2		24.8
99:1 - - - - -		13.3		33.1

Table 3.--Continued

Insecticide (figures indicate percent)	Average dosage per acre	All cucumbers harvested		Marketable cucumbers per acre
		Sound	Wormy	
		Number	Percent	Bushels
1950, Experiment 1 (4 applications at 7- to 8-day intervals)				
Dieldrin 2.5	24 pounds	843	0	255
Lindane 0.06 (suspension spray)	47 gallons	1,059	0.1	333
1	22 pounds	872	.3	273
.5	24	901	.4	273
Aldrin 2.5	27	951	.2	286
Heptachlor 0.24 (suspension spray)	47 gallons	892	.2	268
CS-708 5	23 pounds	832	.5	273
0.125 (emulsion spray)	47 gallons	909	.6	276
Cryolite 70 plus nicotine 2 and lime 5	26 pounds	901	.8	297
70	24	800	1.7	256
TDE 3	24	852	2.4	264
Methoxychlor 10	25	867	2.6	270
Q-137 5	23	787	3.5	237
Metacide 0.028 (emulsion spray)	47 gallons	831	5.7	261
Untreated	-	648	20.1	219
Least significant difference (including untreated plots) at odds of 19:1 - - - - -			2.6	48.6
99:1 - - - - -			3.5	64.8
Least significant difference (excluding untreated plots at odds of 19:1 - - - - -			1.6	-
99:1 - - - - -			2.2	-
1950, Experiment 3 (2 applications at 7-day intervals)				
Sabadilla seed powder 25	28 pounds	873	1	272
25 plus piperonyl butoxide 1	30	891	2	277
25 plus nicotine 2.5	30	874	2	269
Pyrethrins (impregnated) 0.2	26	879	4	278
.2 plus lindane 0.25	25	978	1	285
.2 plus nicotine 2.5	30	826	2	238
.2 plus compound 46 ^a / ₂ 1	26	949	3	297
.2 plus piperonyl butoxide 1	24	783	4	228

^a A commercial product containing 50 percent of (butyl carbityl) (6-allyl-piperonyl) formal and 30 percent of related compounds.

Table 3. --Continued

Insecticide (figures indicate percent)	Average dosage per acre	All cucumbers harvested		Marketable cucumbers per acre
		Sound	Wormy	
		Number	Percent	Bushels
1950, Experiment 3 (continued)				
Pyrethrins (impregnated) 0.075 plus rotenone 0.375 and piperonyl cyclonene 0.75	25 pounds	823	4	255
Rotenone 2	26	982	2	315
1.5	26	845	2	252
1.5 plus nicotine 2.5	26	919	2	284
Allethrin 1	28	808	2	264
1 plus piperonyl butoxide 1	24	781	3	248
Untreated	-	798	6	257
Least significant difference at odds of 19:1 - - - - - ns ^{3/}				-
1951, Experiment 1 (5 applications at 5- to 10-day intervals)				
Lindane 1	20	773	0	190
^{4/} 1	21	856	0.1	194
0.5	20	852	.9	194
Cryolite 50	21	639	5	137
DDT 2 (purified)	20	737	5	169
Parathion 0.5	20	827	9	196
Untreated	-	405	37	108
Least significant difference at odds of 19:1 - - - - - 3.5				34.7
99:1 - - - - - 4.7				46.7
1951, Experiment 2 (1 application)				
Sabadilla 20	36	541	20	173
20 plus nicotine 0.5 and poly- ethylene glycol (600) monolaurate 2	29	536	14	172
Pyrethrins (impregnated) 0.15	25	472	30	162
.1	25	449	31	158
.1 plus lindane 0.25	27	632	10	185
.1 plus piperonyl butoxide 1	25	450	28	151

^{3/} Data not significant according to the F test.

^{4/} Four applications.

Table 3.--Continued

Insecticide (figures indicate percent)	Average dosage per acre	All cucumbers harvested		Marketable cucumbers per acre
		Sound	Wormy	
		Number	Percent	Bushels
1951, Experiment 2 (continued)				
Rotenone 1	25 pounds	490	19	156
Allethrin 1	25	489	26	170
0.5	25	444	31	157
.5 plus compound 46 ^{2/} 2	25	465	24	162
.5 plus piperonyl butoxide 1	25	476	20	163
.5 plus nicotine 0.5 and poly- ethylene glycol (600) monolaurate 2	29	454	26	162
TEPP 0.04 (spray)	73 gallons	480	25	173
Untreated	-	384	27	141
Least significant difference at odds of 19:1		-	8.2	-
99:1		-	10.9	-
1951, Experiment 3 (3 applications at 10- to 14-day intervals)				
Endrin 1	23 pounds	572	0.7	154
Dieldrin 2.5	25	608	2	166
Lindane 1	22	653	2	180
0.5	22	584	4	176
.025 (emulsion spray)	45 gallons	618	4	176
Aldrin 2.5	23 pounds	596	3	167
CS-708 2	21	353	21	112
Nicotine 1 plus bis(p-chlorophenyl) sulfide 4 1 plus polyethylene glycol (600) monolaurate 4	24	186	39	59
	23	267	35	86
Methoxychlor 10	21	403	24	130
Heptachlor 2.5	22	451	24	140
Zineb 4 (product A)	22	248	41	89
(product B)	22	313	26	104
Untreated	-	200	52	71
Least significant difference at odds of 19:1		-	7.7	31.0
99:1		-	10.3	41.4

^{2/} A commercial product containing 50 percent of (butyl carbonyl) (6-allyl-piperonyl) formal and 30 percent of related compounds.

Table 4. --Control of the pickleworm on fall cucumbers treated with several of the most promising insecticide dusts and sprays at various intervals, 1948-50. All insecticides applied as dusts except where sprays are indicated.

Insecticide (figures indicate percent)	Applica- tions	Time between applica- tions	Average dosage per acre	All cucumbers harvested		Marketable cucumbers per acre
				Sound	Wormy	
1948, Experiment 2						
Gamma BHC 1	11	5	20	256	0	79
	10	5, 7	20	306	0.3	92
	9	7	19	268	0	85
	6	10	21	243	0.8	76
DDT 3 (purified)	11	5	20	214	2.3	65
	10	5, 7	20	249	2.7	83
	9	7	19	301	1.0	92
	6	10	21	214	1.8	54
Cryolite 50	11	5	21	278	1.4	93
	10	5, 7	21	264	2.6	92
	9	7	20	243	3.1	78
	6	10	22	235	7.5	67
Least significant difference at odds of 19:1	-	-	-	-	-	-
	99:1	-	-	-	-	-
Gamma BHC 1	6, 11	5, 10	20	1,073	0.3	83
	6, 11	5, 10	20	978	1.9	76
	6, 11	5, 10	21	1,020	3.6	82
	Least significant difference at odds of 19:1	-	-	-	-	-
99:1	-	-	-	-	-	-

Table 4. --Continued

Insecticide (figures indicate percent)	Applica- tions	Time between applica- tions	Average dosage per acre	All cucumbers harvested		Marketable cucumbers per acre
				Percent		
				Sound	Wormy	
1948, Experiment 2 (continued)						
	Number	Days	Pounds	Number	Percent	Bushels
All insecticides	11	5	20	748	1.2	79
	10	5, 7	20	819	1.8	89
	9	7	19	812	1.3	85
	6	10	21	692	3.5	66
Least significant difference at odds of 19:1	-	-	-	-	ns ^{1/}	-
1949, Experiment 2						
Lindane 1	8	7	22	640	0.6	185
	6	10	19	627	3.5	185
1 during prefruiting period, followed by cryolite 50	4	7	17			
DDT 3 (purified)	4	7	29	526	9.3	152
	8	7	22	537	10.0	143
	6	10	19	450	24.7	134
Cryolite 50	8	7	22	432	21.9	136
	6	10	20	258	47.7	85
Methoxychlor 5	8	7	22	273	45.6	82
	6	10	19	164	61.6	44
Untreated	-	-	-	44	86.7	14
Least significant difference at odds of 19:1	-	-	-	-	-	35.4
99:1	-	-	-	-	-	44.7
Lindane 1	6, 8	7, 10	20	1,267	2.1	185
DDT 3 (purified)	6, 8	7, 10	20	987	17.4	138
Cryolite 50	6, 8	7, 10	21	690	34.1	110

Methoxychlor 5	6, 8	7, 10	20	437	52.9	63
Least significant difference at odds of 19:1	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -	24.7
99:1	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -	33.2
All insecticides	8	7	22	1,882	18.0	136
	6	10	19	1,499	30.9	112
Least significant difference at odds of 19:1	- - - - -	- - - - -	- - - - -	- - - - -	<u>2/</u>	17.4
1950, Experiment 2						
Lindane 1	7	7	20	769	0.1	226
	5	10	19	846	0	233
1 during fruiting period only	4	5, 7	27	821	.1	236
			<u>Gallons</u>			
0.058 (emulsion spray)	7	7	40	795	0	229
	5	10	40	900	0	238
			<u>Pounds</u>			
Parathion 1	7	7	22	831	.1	245
	5	10	19	844	.4	251
1 during fruiting period only	4	5, 7	28	775	.4	203
DDT 3 (purified)	7	7	20	818	.5	228
	5	10	20	808	.5	223
3 during fruiting period only	4	5, 7	27	843	.4	257
Cryolite 70	7	7	20	882	.2	248
	5	10	21	802	.9	241
	4	5, 7	30	777	.6	215
Untreated	-	-	-	714	9.2	207
Least significant difference at odds of 19:1	- - - - -	- - - - -	- - - - -	- - - - -	2.1	ns
99:1	- - - - -	- - - - -	- - - - -	- - - - -	2.8	-

1/ Data not significant according to the F test.

2/ Differences required for significance not given as they were based on an analysis of variance of angular values (degrees) of the percentage figures involved.

Table 4. --Continued

Insecticide (figures indicate percent)	Applica- tions	Time between applica- tions	Average dosage per acre	All cucumbers harvested		Marketable cucumbers per acre
				Sound	Wormy	
1950, Experiment 2 (continued)						
Lindane 1	4, 7	5, 10	22	2,436	0.1	232
Parathion 1	4, 7	5, 10	23	2,450	.3	233
DDT 3 (purified)	4, 7	5, 10	22	2,469	.4	236
Cryolite 70	4, 7	5, 10	24	2,461	.6	235
Least significant difference at odds of 19:1 - - - - - ns						
All insecticide dusts	7	7	20	3,300	.2	236
	5	10	20	3,300	.4	237
(during fruiting period only)	4	5, 7	28	3,216	.4	228
Least significant difference at odds of 19:1 - - - - - ns ^{1/}						

1/ Data not significant according to the F test.

Table 5.--Infestations of the melon aphid on fall cucumbers treated with several insecticides for pickleworm control, 1951. All insecticides applied as dusts unless otherwise indicated.

Insecticide (figures indicate percent)	Average dosage per acre	Melon aphid index rating ^{1/}	
		Count 1	Counts 1 and 2
<u>Pounds</u>			
Experiment 1 (5 applications at 5- to 10-day intervals)			
Parathion 0.5	20	0	3
Lindane 1 (4 applications)	21	8	25
1	20	5	32
0.5	20	16	44
DDT 2 (purified)	20	78	221
Cryolite 50	21	247	701
Untreated	-	40	108
Least significant difference at odds of 19:1 - - - - -		53.1	100.5
99:1 - - - - -		71.5	135.4
Experiment 3 (3 applications at 10- to 13-day intervals)			
Dieldrin 2.5	25	8	25
Endrin 1	23	5	37
Lindane 1	22	9	50
0.5	22	17	77
Aldrin 2.5	23	23	65
Heptachlor 2.5	22	38	268
Methoxychlor 10	21	201	597
CS-708 2	21	313	997
Nicotine 1 plus bis(p-chlorophenyl) sulfide 4	24	293	1,025
1 plus polyethylene glycol (600)			
monolaurate 4	23	304	1,082
Zineb 4, product B	22	336	822
product A	22	357	1,165
<u>Gallons</u>			
Lindane 0.025 (emulsion spray)	45	16	79
Untreated	-	130	745
Least significant difference at odds of 19:1 - - - - -		141.4	345.2
99:1 - - - - -		188.6	460.4

^{1/} Counts were made 1 week apart during the middle of the harvesting period.

Table 6. --Residues on cucumber fruits dusted with different insecticides, 1948-50

Insecticide (figures indicate percent)	Average dosage per acre	Applica- tions	Date samples were---		Time between last applica- tion and sampling	Residue on fruits	
			Taken	Examined		Unwashed	Washed or brushed
Pounds	Number			Days	P.p.m.	P.p.m.	
Gamma BHC 1	20	10	Oct. 1948	-	0	1/ 12.2	7.7
		8	May 23, 1949	June 2, 1949	0	None	-
			25	2	2	do.	-
			27	2	4	do.	-
			June 6	10	14	do.	-
Lindane 1	16	5	May 23	2	19	do.	-
	21	7	Oct. 4	-	0	0.8	0.8
		1	June 6, 1950	-	13	.4	-
		2	6	-	0	.4	-
	16	4	Oct. 4, 1949	-	21	.6	.6
Cryolite 50	28	3	4	-	0	2.0	.2
	20	10	Oct. 1948	-	0	2.4	1.1
	19	8	May 23, 1949	June 3, 1949	0	36.0	-
			June 13	23	21	9.6	-
	20	9	13	23	0	82.0	16.2
DDT 3 (purified)	21	7	Oct. 4	-	0	1.4	None
	18	8	May 23	June 1	0	None	None
	21	7	Oct. 4	-	0	.8	.8
	22	1	June 6, 1950	-	13	.6	-
	22	2	6	-	0	1.6	-
Parathion 1	18	8	May 23, 1949	June 2, 1949	0	.03	-
	23	5	Oct. 7	-	0	.3	-
Methoxychlor 5	21	7	4	-	0	1.3	1.2
Untreated	-	-	4	-	-	.2	-

1/ Outer portions of the unbrushed fruit contained 20.4 p.p.m. and those of the brushed fruit 12.9 p.p.m.