STUDIES ON CONTROL OF THE EUROPEAN PINE SHOOT MOTH, RHYACIONIA BUOLIANA [SCHIFFERMILLER]

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STUDIES ON CONTROL OF THE EUROPEAN PINE SHOOT MOTH, *RHYACIONIA BUOLIANA* (SCHIFFERMILLER)

By

WILLIAM STANWOOD CATH

A THESIS

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

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AN ABSTRACT

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AN ABSTRACT

This thesis is concerned with the study of the chemical control of the European pine shoot moth, *Rhyacionia buoliana* Schiffermiller. The five insecticides used were endrin, heptachlor, DDT, dieldrin, parathion and a combination of DDT and parathion.

Spray areas were located in Ingham, Clinton and Shiawassee Counties in Michigan. Each spray area was divided into ten plots with twelve trees in each plot. Each treatment was applied to one tree, selected at random, in each plot. Effectiveness of the sprays was determined by calculating the per cent of infested shoots. Counts were made eight weeks after the last application. Sprays were applied by a three gallon knapsack sprayer. The trees used for this study were red and Scots pine.

At the Ingham County plots there were two applications of a single dosage of the five insecticides; the second application was applied within a week of the first. The DDT-parathion mixture was applied the second week as a single application.

At the Clinton County plots, a double dosage of DDT, heptachlor, endrin, dieldrin and parathion was applied first and within a week a single dosage of the same materials was applied, as well as a single dosage of the DDT-parathion mixture.

The trees in Shiawassee County were sprayed with single and double dosages of all the materials, with the exception of the DDT-parathion mixture, on the first spray date. The DDT-parathion mixture spray date coincided with that of Ingham and Clinton Counties.

As a result of this study, it was found that the materials used as a means of controlling R. buoliana were either highly effective or relatively non-effective. The insecticide that gave the greatest degree of control was DDT but parathion and the DDT-parathion mixture closely approximated it. The materials that gave very poor results, although used at higher dosages than recommended by their manufacturers, were dieldrin, endrin and heptachlor and were effective in that order, dieldrin being the best of the three.

The data indicated that as good control was obtained by applying a single dosage during the first or second week of larval activity as by applying a double dosage the first week.

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INTRODUCTION

The European pine shoot moth, *Rhyacionia buoliana* Schiffermiller, is a member of the family Olethreutidae, which belongs to the order Lepidoptera. For years it has assumed the role of one of the major pests of the pine forests of Europe. Since its introduction into the United States in 1913, the moth has established itself as a threat to our native and ornamental pines.

In Michigan the outbreak of this pest has been spotty although most of the counties south of Town Line 16 have areas with some degree of infestation. The heaviest-hit locations occur in Muskegon, Ottawa, Ingham, Lenawee, Monroe, Wayne and Washtenaw Counties. These seven counties are all south of Town Line 16. North of Town Line 16, outbreaks of *R. buoliana* were confined to certain definite areas located on the coast of Benzie and Alcona Counties and an area including the east of Manistee and the west of Wexford Counties.

One method of controlling this insect is the use of insecticides.

This investigation is concerned with the comparative effects of five insecticides as means of controlling the European pine shoot moth on red and Scots pines under plantation conditions. Under these circumstances, these species used as ornamentals or planted in the nursery may be subject to the same control methods; however, the size of the trees would be a factor that might make other methods of control seem more feasible.

REVIEW OF LITERATURE

Historical Background

Rhyacionia buoliana Schiffermiller has experienced many changes in its generic classification. Schiffermiller first described the species as Tortrix buoliana in 1776, naming it in honor of a Viennese entomologist, Baron Buol, who studied its injurious work during the latter part of the eighteenth century. It has since undergone the following taxonomic changes: Coccyx buoliana Treitschke, 1830, Tortrix (Coccyx) buoliana Ratzeburg, 1840, Retinia buoliana Guenee, 1845, Coccyx buoliana Herrick-Schaffer, 1849, Evetria buoliana Meyrick, 1895, Evetria buoliana Rebel, 1901 and only recently it has been placed in the genus Rhyacionia. Numerous accounts have appeared of particularly severe outbreaks in many parts of Europe, from England to Russia, from Scandinavia to southern France and as far north as Siberia (Busck 7). The following accounts are a few listed by Busck. One outbreak in Denmark, 1805-1807, was so serious that it nearly caused pine culture to be abandoned in that country as hopeless. Ratzeburg mentioned an outbreak in 1836-1838 which reached such proportions that it was under consideration to burn off the area and plant new trees. Judeich and Nitsche recorded an outbreak where 75 acres of young pines presented a pitiful, crippled appearance from infestation by R. buoliana. The

Belgian authority on forest insects, G. Severin, regarded R. buoliana as the most injurious insect to pines in Europe.

Webber (34) wrote of a survey he made in Poland where he found that the northwest portion of the country was heavily infested with the shoot moth.

R. buoliana was first discovered in the United States at Great Neck, Long Island on European pine seedlings by Busck in 1913 (Felt 10). By July 1, 1915, the importation of pine trees from Europe had been forbidden by the United States Department of Agriculture under a quarantine order (Brown 5). It was first recorded by McDaniel (22) in Michigan from the general area of Detroit, Ann Arbor and Monroe in 1930. Since its discovery in the United States, the European pine shoot moth has infested pines in the following geographical areas: Michigan, Illinois, Ohio, West Virginia, Pennsylvania, New Jersey, New York, Massachusetts, Connecticut, Rhode Island and Florida (Craighead 8).

In Canada, an infested shipment of trees imported to Windsor, Ontario in 1924 was detected but it was learned soon after that areas in Toronto, St. Catharines and Niagara Falls were already infested (McLaine 24). McLaine (25) also stated that in the fall of 1926 all pines imported from Europe since the inauguration of the permit system were inspected with the result that infestations were found at 45 points in Ontario. According to Twinn (32), since 1926 the European pine shoot moth established itself in Nova Scotia, British Columbia and extensively in southern Ontario along the shore of Lakes Erie and Ontario.

Biology

The adults of *R. buoliana* have brown-red forewings conspicuously marked with irregular, silvery cross lines. There are six of these lines starting from the anterior border. The hind wings are grey-brown with a red tinge at the tip and the frenulum consists of three spines in the female and one in the male. According to West and Friend (35) "the wing spread varies between 18 and 24 mm.". The body is heavily clothed with tan or buff scales and there is a somewhat lighter, conspicuous tuft situated on the head over the bases of the antennae. The antennae are dark-colored, filiform and more than half the length of the body.

The sexes can be distinguished by the appearance of the abdomen. In the female this is swollen and has the ventral side of the tip covered with a tuft of brown hairs and scales. The male abdomen is more slender, with parallel sides and the tip is furnished with long hairs (West and Friend 35).

The egg is elliptical, with a flat under-surface and a convex upper-surface. Newly laid eggs are yellow and change to red-brown as the embryo progresses. Just before hatching, the complete larva may be seen within and the head capsule stands out distinctly as a black spot.

Observations made by West and Friend (35) showed that in the second instar, the body was red-brown, being much darker than in the first, and the third and fourth instars were similar in appearance to the second. During the fifth and sixth instars, the larvae were lighter in body color. In these last two stages, the prothoracic and anal shields were much more distinct than in the earlier stages.

The pupa is dark yellow-brown and measures approximately ten millimeters in length. West and Friend (35) described it as having a somewhat prominent ridge extending from the frontal region to the back of the head. On the dorsal side the most prominent feature is the rows of spines on each of the abdominal segments. There are two rows on segments two through seven inclusive and one row on each of the remaining segments.

The insect here, as in Europe, is single-brooded and the adults fly during June and the first part of July (Friend 12). Studies by West and Friend (35) showed that males predominated among the adults emerging during the first part of the emergence period, that females predominated during the latter part and that males lived a shorter time than females. They also found that the average pupation period of the male was slightly less than the female.

The adults may be seen at dusk on warm, quiet days fluttering around the trees. Greenfield (19) stated that when the moths were present in large numbers, the trees seemed to be enveloped in a white cloud. Friend and Hickock (13) considered that the two most important agencies which operated to disperse the insect were adult flight, aided by wind, and transportation of larvae in trees used for ornamental planting. They observed that the adults did not tend to fly far, but hovered about the vicinity of the trees in a restricted locality.

The preoviposition period is not very long according to West and Friend (35). They found the shortest preoviposition period in 21 cases was two days from the time of emergence and the longest period was five days.

McDaniel (23) observed that the eggs were laid singly on the buds and needles and on the twig close to the bud. The writer, however, observed many eggs laid in clusters of three or four on the needles (Plate 1, page 60). West and Friend (35) stated that there was a ten day incubation period in Connecticut. In southern Ontario, DeGryse (9) found that the incubation period was from ten to eighteen days depending upon whether the eggs were laid in late June or early July.

The larvae begin feeding on the needle bases upon hatching. Frequently a web is spun between the bark of the twig and the opening of the burrow. The burrow opening itself is always covered with a web (DeGryse 9). Observations by Friend and West (35) showed that by the end of the first week in July most of the larvae were boring into the buds. At the time they bore into the buds they may be easily detected by the pitch on the infested buds and by the appearance of dead needles at the tip of branches. Often the larvae eat the bark of the new growth or bore into the soft wood of the new shoot.

Hibernation occurs inside the bud, under the pitch mass on the bud or between them (Plate 2, page 60). The larvae pass through six instars, the first three of which occur in the month of July, and hibernation takes place as a rule while the larvae are in the sixth instar. Studies in Canada by DeGryse (9) showed that the larvae were in the fourth instar while hibernating, but a few hibernated in the third and fifth instars. Some larvae may be active during warm days in winter. By the middle of May, practically all larvae are in the fifth and sixth instars and thereafter the sixth instar predominates. West and Friend (35) found that the presence of the larva of _Battaristis vitella_ Busck, a Gelechiid in the buds of red pine, was sometimes confusing as the larva bored into the buds in the fall and hibernated there.

Pupation of _R. buoliana_ occurs after the middle of May following a pupal period of two to three weeks. The pupa remains in the larval burrow until the adult is ready to emerge, at which time it wriggles out until most of the body is exposed. The emerging adult leaves the cast pupal skin projecting from the shoot where it is easily observed (Plate 3, page 61). These facts were evidenced by Friend (11).

The following European and North American pines have been recorded as host plants of R. buoliana according to West and Friend (35): Scots pine (Pinus sylvestris), Austrian pine (P. nigra), Corsican pine (P. nigra var. poirethana), cluster pine (P. pinaster), mugho pine (P. mugo var. mughus), white pine (P. strobus), red pine (P. resinosa), digger pine (P. sabiniana), ponderosa pine (P. ponderosa), loblolly pine (P. taeda), lodgepole pine (P. contorta), jack pine (P. banksiana), prickle cone pine (P. muricata), long leaf pine (P. palustris), Japanese red pine (P. densiflora), Italian stone pine (P. pinea) and aleppo pine (P. halepensis).

McAndrews (21) found that in 1935 at Syracuse, New York, some buds in a spruce planting adjoining a mixed pine plantation were infested with shoot moth. A few of them survived and persisted on the Norway spruce in succeeding years. The shoot moth has been found on white pine in Ontario and the writer has also found a high percentage of infested white pine on federal, Soil Conservation Service and private plantations in Ottawa County, Michigan, where the adjoining red and Scots pine had suffered heavily from this insect. Surveys made by Watson and Raizenne (33) in 1946 showed that R. buoliana continued to be the most destructive pest of hard pines in southern Ontario.

Balanced populations at high density are relatively rare in the forest. They usually occur under forest conditions that are abnormal and they injure trees without killing them

outright. The European pine shoot moth is a good illustration of this population type (Graham 18). Friend, Plumb and Hickock (17) stated that the principal injury caused by the insect was that of boring into buds in the fall and into developing shoots in the spring. The death of buds and shoots lead to the development of latent buds just below the tip of the twig with a consequent bushy type of growth (Plate 4, page 61). When infestation was severe, terminal growth was inhibited and, because little new growth survived to produce needles, a progressive defoliation of the tree took place. If the attacked growing shoot was not killed, it became badly distorted and if this occurred on the terminal shoot of the tree, the main stem became permanently curved. This is the so-called "posthorn" or "bayonet" (Plate 5, page 61).

Observations by McAndrews (21) showed that on severely injured tips of red pine, the needles were abnormal and were short, dark green, stout and three to a fascicle with confused resin canals.

Ryle (28) reported extensive needle damage to Scots pine in England.

Further studies by Friend, Plumb and Hickock (17) showed that the larval population of R. buoliana in red pine stands was concentrated in the tops of trees. McDaniel (23) stated that mature trees will be attacked but aside from serving as "brood trees" such attacks are of little importance.

Based upon studies made by McAndrews (21), some species of pine were more susceptible to attack than others when the larval population per bud was the same. The ability to recover from injury varied with the species.

Controls

The northern limit of R. buoliana is considered to be the annual minimum isotherm of $-10^{O}F$ and temperatures approximating or exceeding this have been found to greatly increase the winter larval mortality. It was found by Friend and Hickock (15) that the reason for the decrease in the abundance of this insect in Connecticut in 1935 was due to the very cold weather during the winters of 1932, 1933 and 1934. Studies by West (36) confirmed those made by Friend and Hickock.

Twinn (30), in writing of the forest insect status of Ontario, mentioned that the severe winter of 1933-1934 resulted in a remarkable reduction of the European pine shoot moth in the infested areas in southern Ontario to the north of Lake Erie. In 1937, Twinn (31) wrote of the considerable recovery of the shoot moth in the Niagara district of Ontario where it was largely eliminated by the severe weather of 1933-1934. Brown (4) also stated that the European pine shoot moth continued its steady recovery from the cold winters of 1933 and 1934 along the shores of Lakes Erie and Ontario.

Parasitism of R. buoliana has not contributed greatly to the reduction of this species in America (Berry and Dowden 1). According to Berry and Dowden (1), twelve hymenopterous and two dipterous parasites of R. buoliana were liberated by the Bureau of Entomology and Plant Quarantine. Three species of these are known to have become established.

R. buoliana is primarily found on ornamental or pine plantings from nursery stock; therefore, the initial problem of control has not been as great as it could be if this insect occurred under strictly forest conditions. Friend (12) stated that when dead needles and conspicuous pitch accumulations on the buds were apparent, the infested tips should be cut off and burned. If heavily infested trees were found, they should be cut and burned.

Hamilton (20) found that the European pine shoot moth could be controlled by spraying infested trees during June with Penetrol (an oxidized sulfonated gas-tar oil) plus "Black Leaf 40". He also sprayed severely infested trees with "Pineol soluble", "Penetrol" and a miscible pine oil diluted so that it contained 2% and 4% actual pine oil. "Black Leaf 50" was added to each spray material. The results showed no kill in any of the sprayed plots. Rather severe burning occurred on the needles in the solutions where Penetrol and the pine oil were used. Summer applications of Penetrol proved safe on the foliage with repeated sprayings and were very effective in killing the adults and the eggs.

In experiments conducted by Friend and West (14) it was found that sprays using Verdol plus lead arsenate, fish oil plus lead arsenate, nicotine sulfate and the Penetrol-lead arsenate mixture, and nicotine sulfate and the Penetrol-lead arsenate mixture gave very good kill. However, it was found that Verdol caused extensive burning of the needles and the nicotine-Penetrol mixture proved too costly. Experiments with three applications of calcium arsenate dusts failed to give results. Friend and West also reported that Glascow secured excellent results with rotenone spray.

Experiments carried on by Friend and Plumb (15) showed that spraying with a mixture of four pounds of ground derris root in 100 gallons of water plus one pound of powdered skim milk was superior to spraying with a mixture of three pounds of lead arsenate and one pint of fish oil in 100 gallons.

From studies made by Bartlett Tree Research Laboratories, Bromley (3) stated that the European pine shoot moth could be controlled by spraying either with arsenate of lead or Styx (a pyrethrum rotenone insecticidal oil mixture formulated at the Bartlett Tree Research Laboratories) after the eggs had hatched and the young larvae were feeding.

J. G. Rodriguez and Dr. R. B. Neiswander in 1949 at Ohio State University found mist applications, using DDT in four concentrations, to be of no value (Miller 26). Miller at Ohio State University worked on five tip, twig and shoot moths and found that spray formulations of a material gave

better control than dust formulations of the same material. He also found DDT to be the most superior material and two tests showed that one pound of actual DDT in 100 gallons of water applied as a single treatment gave as good a control when applied at the right time as a two pound formulation. Tests were conducted in 1950 by Miller with the following materials: DDT, parathion, EPN, rotenone, chlordane and toxaphene. Results showed that two applications of four pounds of a 50% DDT wettable powder in 100 gallons of water gave the best control. Two formulations of parathion were used and it was found that one application of two pounds of a 15% wettable powder and a 1% dust gave good controls also. The remaining insecticides gave lower degrees of kill. Tests were also conducted in 1951 with the following materials in 100 gallons of water and showed the corresponding per cent of control: metacide 1½ pints--99%; 2 3/4 pounds 75% DDT--99%; 2 pounds 15% parathion--97%; 1½ pints 47% malathion--95%; 28 pints 25% DDT--75%; and 6 pounds 25% dieldrin--68%. Two gallons of a 25% parathion emulsion in 50 gallons of water and 6 gallons of a 25% DDT emulsion in 50 gallons of water were applied by airplane in 1951. The results were not very satisfactory as the parathion mixture gave 88% control and DDT gave 60%.

Porter (27) suggested the following insecticides for the control of the European pine shoot moth in Ohio nurseries:

2 pounds of actual DDT, 2½ pounds of 15% wettable parathion or 4 pounds of 6% rotenone in 100 gallons of water.

In June of 1953, federal, county and private acreages of red and Scots pine plantations in Ottawa County, Michigan, were sprayed for R. buoliana by the County Soil Conservation Service in conjunction with private land owners. A Piper Cub with a forty gallon tank and equipped with spray booms under the wings was assigned to the job. Approximately one pound per acre of 15% DDT was applied. Random counts in the fall of 1953 by the author showed that in two of the red pine plantings counted, the percentage of infestation was still very high.

EXPERIMENTAL METHODS

Procedure

The trees used in this study were located in three different counties in Michigan. In each area the level of infestation was great enough to permit an accurate determination of the per cent of control after treatment. These three plots were located in Ingham County at Michigan State College at the Red Cedar Woodlot, in Clinton County at Rose Lake Wildlife Experiment Station on the corner of Upton and Stoll Roads, and in Shiawassee County at Robert Young's (private land owner) just past Rose Lake Wildlife Experiment Station on Michigan Highway 78.

Most of the trees used in this study were approximately two to three feet high, although some of them were as small as one to one and a half feet high.

The Rose Lake plots consisted of all red pines, while Young's plots were predominantly red, with a few Scots, pine intermingled. The Red Cedar plots at Michigan State College were a 50-50 mixture of red and Scots pine.

All spray materials were applied with a three-gallon knapsack sprayer having a fan type nozzle. Water for mixing the spray materials was drawn from the Michigan State College water supply and was carried in a 54 gallon drum mounted on the back of a jeep.

The materials used in this study were endrin, heptachlor, DDT, dieldrin, parathion and a mixture of DDT and parathion (Table I, page 32).

In April of 1953, the spray program in each area was set up in randomized plot form by selecting ten plots with twelve trees in each plot. All of these trees were tagged and on each tag was recorded the spray material to be used and the dosage. This was done with red, blue and black china marking pencils so that alternate rows of trees would have different colored tags, facilitating the location of trees within a plot. The arrangements of the plots and treatments within each are shown in Maps 2, 3 and 4 on pages 48, 49 and 50.

At the Red Cedar Plots (Map 2, page 48) there were two applications of a single dosage of the first five insecticides; the second application was within a week of the first. The DDT and parathion mixture was applied on the second week as a single dosage.

At the Rose Lake plots (Map 3, page 49) a double dosage of DDT, heptachlor, endrin, dieldrin and parathion was applied at first and within a week a single dosage of the same materials was applied, as well as a single dosage of the DDT-parathion mixture.

The trees on Young's property (Map 4, page 50) were sprayed with a single and a double dosage of all the materials, with the exception of the DDT-parathion mixture, on the first spray date. The DDT-parathion mixture spray date coincided with that of the Rose Lake and Red Cedar areas.

By utilizing different spray dates and different dosages, a better picture of the relationship of timing and dosages was obtained. This was done by applying a single dosage on the first and second week and a double dosage on the first week. There was no double dosage applied during the second week because it was felt that the insect activity had passed its peak and from a nurseryman's standpoint, it was economically unsound. The DDT and parathion mixture was applied only as a single dosage on the second spray date. For materials and dosages used, see Table I, page 32.

Starting on May 2, 1953, daily observations were made of one or more of the spray areas to determine when the adults emerged and egg-laying began.

On May 24, pupae were reported to be present in the Kellogg Forest at Battle Creek and by June 2, they were found in all of the author's spray plots. Extruding pupal cases were found on June 9 and by June 11, adults were collected from all three plots. Dr. Walter F. Morofsky of the Entomology Department at Michigan State College reported that the adults in Michigan were first observed on June 19 for the last four years.

Copulation and oviposition was immediately noticeable and a collection of shoots infested with eggs were made. These were caged by the author and placed out-of-doors in a readily observable place in order to record the time of hatching.

On June 17 the eggs on the caged material had hatched and on June 20, single and double dosages of endrin, heptachlor, DDT, dieldrin and parathion were applied at Young's plots. A double dosage of the same materials was applied at the Rose Lake plots and a single dosage was applied to the Red Cedar plots on this same date.

The second spray was applied on June 27. From observations made following this date, it appeared that the larval populations were the highest and adult activity had reached its peak on or about June 27, although it was not until July 7 that all adult activity had ceased. Single dosages of endrin, heptachlor, DDT, dieldrin and parathion were sprayed on trees at Red Cedar and Rose Lake plots on June 27. The DDT-parathion mixture was also applied as a single dosage at all three areas.

On June 20 the daily average temperature was 93^{o} and there was very little wind. On June 27 the daily average temperature was 83^{o} with a wind velocity of approximately fifteen miles per hour. These high temperature readings possibly contributed to the effectiveness of parathion because it is only partially effective at low temperatures. Rain occurred on the night of June 20 and could have caused a reduction of the potential effectiveness of the spray materials by washing off some of the residue from the trees.

The author based the formulations for the insecticides used in this study at a slightly higher dosage than their manufacturers recommended for lepidopterous larvae because *R. buoliana* is exposed to these materials for a relatively short time and the possibility of ideal weather conditions, such as effective temperatures and absence of rainfall, could not be ascertained.

When injury, such as exuding pitch and dying needles, became apparent, infestation counts were made at the three spray areas. Counts were taken at Rose Lake on August 14 and at Red Cedar and Young's plots on August 15, 1953. This was done by recording the total number of shoots and the number of infested shoots on each tree (Tables II to VII, pages 33 to 38).

Data in the remaining tables and graphs of this thesis are based on these original infestation counts.

EXPERIMENTAL RESULTS

For the sake of clarity, the data presented in the next few pages have been considered according to spray plots and spray dates. "Reduction from check" was calculated by using Abbott's formula (Shepard 29).

Red Cedar Plots

Trees treated on June 20 with single dosages of endrin, heptachlor and dieldrin showed a high percentage of infestation in all plots except numbers 7 to 10. It was noted that in Plot 7 there was no infestation on any treated tree. The untreated tree was not infested either. The degree of infestation fluctuated greatly on trees treated with these three compounds and in some plots it even exceeded the per cent of infestation in the untreated trees. Both DDT and parathion treated trees showed a very low percentage of infestation and in Plots 4 to 10 there was no infestation on any of the trees treated with these materials (Graph 1, page 51). The average percentages of infestation of trees in the ten plots treated with endrin, heptachlor and dieldrin were higher than the average of the untreated trees. On the other hand, both DDT and parathion were considerably lower. The percentage of reduction from the check again reflected the better controls obtained by the parathion and DDT. The parathion spray gave a 95.2% reduction and the DDT spray gave 93.9% reduction, while endrin and heptachlor gave no reduction at all. Dieldrin only showed a reduction of 2.4%. (Table VIII, page 39 and Graph 7, page 57).

The effects of a single dosage of these materials sprayed June 27 gave relatively the same results and again all the trees treated in one plot (this time Plot 9) showed no infestation except the heptachlor treatment which was only 10% (Graph 2, page 52). The infestation of endrin, heptachlor and dieldrin treated trees again exceeded that of untreated trees in almost every plot except 3. Good control was obtained by parathion and DDT and also by the mixture of DDT and parathion. In Table IX and Graph 7, pages 40 and 57, the DDT-parathion mixture gave a 99.1% reduction from the check, parathion gave 90.4%, DDT gave 97.6% and the other three materials did not give a reduction.

Rose Lake Plots

A double dosage of spray materials applied June 20 resulted in a pattern of extremes as endrin, heptachlor and dieldrin gave very little control and parathion and DDT gave very good results (Graph 4, page 54). Heptachlor in no plot showed more than 20% control. In Plot 1, endrin gave 71% control, but in the other nine plots it never exceeded 24%. Dieldrin in Plot 2 gave 75% control but in all others 25% was the highest recorded.

As in the Red Cedar plots, trees treated with parathion and DDT showed the lowest percentage of infestation. The highest for either material was 13% in Plot 6 for DDT.

The percentage of reduction from the check percentage in the case of endrin, heptachlor and dieldrin was never more than 15% while DDT equalled 98.1% and parathion 97.4% (Table X, page 41 and Graph 8, page 58).

Single dosages that were sprayed on June 27 reacted in the following ways: endrin followed an erratic pattern as it showed no infestation in one plot and in the preceding and succeeding plots it showed one hundred per cent infestation. Heptachlor and dieldrin registered a high percentage and parathion, DDT and the DDT-parathion formulation showed a low percentage, DDT being the better of the three materials (Graphs 3, page 53, and 8, page 58). The average per cent of reduction from the check as shown in Table XI, page 42, indicated that endrin was the only material that showed an increase in percentage while all other materials maintained about the same level of previous figures on the Red Cedar and Rose Lake plots. The results of this dosage also pointed out that the infestation in endrin, heptachlor and dieldrin treated trees at times exceeded the infestation of untreated trees.

Young's Plots

Single dosage applications on June 20 resulted in a smaller percentage of infestation for all materials used, especially endrin, heptachlor and dieldrin. In Graph 5, page 55, the percentage recorded for individual plots and in Table XII, page 43, the average percentage for all plots indicated a decline from the results obtained on the other two areas considered. However it was also noted that the per cent of infestation of untreated trees was correspondingly lower so that the net results were not significant.

DDT and the DDT-parathion mixture (sprayed June 27) showed no infestation after treating, while parathion alone had a slight increase of infestation as compared to other areas.

As shown in Graph 9, page 59, DDT and the DDT-parathion mixture showed one hundred per cent reduction from the check while parathion alone had 73.9%. Endrin and dieldrin gave no reduction and heptachlor only 5%.

The per cent of infestation on endrin, heptachlor and dieldrin treated trees again exceeded that of untreated trees in many of the plots.

June 20 sprays of double dosages of these materials resulted in a rather systematic reduction of infestation in individual plots in accordance with the infestation of untreated trees in those plots. Heptachlor was the only material that showed a percentage of infestation greater than the untreated trees in the majority of the plots. From Plots 2 to 10, endrin and dieldrin gave almost similar results with endrin giving a slightly higher percentage of infestation. Parathion and DDT followed the same pattern as shown in all other areas by having a very low percentage of infestation (Graph 6, page 56).

In Table XIII, page 44, the average per cent of infestation of the double dosages shown are: endrin 25.7%, Heptachlor 43.5%, dieldrin 17.5%, DDT 1.5% and parathion .4%. These percentages indicated a rather low amount of infestation for endrin, heptachlor and dieldrin; however, as shown in Table XIII, page 44, and Graph 9, page 59, the real measuring stick of the effectiveness of these materials was the per cent reduction from the check and dieldrin with a 61.7% reduction was the only insecticide of the three to exceed 50%. The 43.8% reduction recorded for endrin was a slight increase but heptachlor made no gains at all. In Plot 7, all of the treated trees excepting the endrin treated one showed no infestation while the untreated one showed a 64% infestation. The infestation on the endrin treated tree was only 10%. Parathion and DDT again displayed a very low percentage of infestation and a high percentage of reduction from the check. Parathion was the highest with a 99.2% reduction and DDT close behind with 97.8%.

SUMMARY AND CONCLUSIONS

It was apparent throughout the spray tests that DDT, parathion and the DDT-parathion mixture gave the best controls of the six materials used (Tables XIV and XV, pages 45 and 46). This statement is based on the fact that although the average percentage of infestation in the Rose Lake plots was approximately double the amount of Red Cedar and Young's, these three materials still gave the same high percentage of reduction. DDT and parathion were applied as a single dosage on June 20 and 27 and as a double dosage on June 20. The results obtained from these spray dates indicated that as good control was obtained by applying a single dosage during the first or second week of larval activity as by applying a double dosage the first week. The DDT-parathion mixture was applied only as a single dosage on June 27, but the effectiveness of this mixture was equal to that of parathion or DDT.

Endrin when applied as a single dosage on June 20 at Red Cedar and Young's plots gave little or no control at all. This was also true with heptachlor and dieldrin. Single dosages of endrin, heptachlor and dieldrin gave the same poor showing at Red Cedar and Rose Lake plots when applied on June 27. Double dosages of endrin and dieldrin sprayed on June 20 at Rose Lake and Young's plots gave a 25.5% and 38.8%

average reduction from the check which was an increase from the 4.4% and the 1.2% reductions caused by a single dosage. Heptachlor, however, showed very little increase in reduction as a double dosage as against a single dosage. The average reduction from the check of a single dosage was 2.2% and for a double dosage 2.7%.

As a result of this study, it was found that the materials used as a means of controlling R. buoliana were either highly effective or relatively none-effective. The insecticide that gave the greatest degree of control was DDT, but parathion and the DDT-parathion mixture closely approximated it. The materials that gave very poor results were dieldrin, endrin and heptachlor and were effective in that order, dieldrin being the best of the three.

The most effective spray date for the application of insecticides for the control of R. buoliana was June 20, at which time insect activity and temperature requirements were at their optimum.

Endrin, heptachlor and dieldrin, when used at the dosages utilized in this study, were relatively ineffective although used at a higher dosage than that recommended by their manufacturers.

On the basis of the cost of materials alone, it would seem more economical for nurserymen to use DDT rather than parathion, as DDT is less expensive and is much less toxic to handle.

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APPENDIX

TABLE I

SPRAY MATERIALS AND DOSAGES USED AT RED CEDAR, ROSE LAKE AND YOUNG'S PLOTS

Materials in 3 gallons of water	Single dosage	Double dosage
Endrin (25% emulsifiable conc.)	3/4 fl. oz.	1½ fl. oz.
Heptachlor (25% emulsifiable conc.)	3/4 fl. oz.	1½ fl. oz.
DDT (75% wettable powder)	2¼ oz.	4½ oz.
Dieldrin (50% wettable powder)	3 oz.	6 oz.
Parathion (15% wettable powder)	1½ oz.	3 oz.
Parathion (15% wettable powder) and DDT (75% wettable powder)	1½ oz. 2¼ oz.	

TABLE II

INFESTATION COUNTS OF TREES TREATED WITH SINGLE DOSAGES OF INSECTICIDES AT RED CEDAR PLOTS
(Sprayed June 20, 1953; counted August 15, 1953)

	Plot									
	1	2	3	4	5	6	7	8	9	10
Endrin 3/4 fl. oz. 25% emulsifiable concentrate*										
Total shoots/tree	15	16	54	17	20	10	9	18	6	13
Infested shoots/tree	14	15	30	16	20	5	0	0	0	9
Heptachlor 3/4 fl. oz. 25% emulsifiable concentrate*										
Total shoots/tree	14	8	36	15	7	11	7	10	11	5
Infested shoots/tree	12	6	16	14	4	7	0	3	6	2
DDT 2¼ oz. 75% wettable powder*										
Total shoots/tree	9	18	22	7	11	11	10	7	4	13
Infested shoots/tree	2	0	1	0	0	0	0	0	0	0
Dieldrin 3 oz. 50% wettable powder*										
Total shoots/tree	27	26	36	20	8	5	4	16	6	7
Infested shoots/tree	21	24	11	20	4	2	0	9	0	0
Parathion 1½ oz. 15% wettable powder*										
Total shoots/tree	18	58	32	15	21	4	7	6	4	18
Infested shoots/tree	1	6	0	0	0	0	0	0	0	1
Untreated										
Total shoots/tree	27	39	8	40	11	21	5	15	3	10
Infested shoots/tree	19	32	7	39	6	5	0	3	0	2

* in three gallons of water

TABLE III

INFESTATION COUNTS OF TREES TREATED WITH SINGLE DOSAGES OF INSECTICIDES AT RED CEDAR PLOTS
(Sprayed June 27, 1953; counted August 15, 1953)

	Plot									
	1	2	3	4	5	6	7	8	9	10
Endrin 3/4 fl. oz. 25% emulsifiable concentrate*										
Total shoots/tree	53	12	42	50	7	17	25	3	6	8
Infested shoots/tree	33	9	27	32	6	4	16	0	0	3
Heptachlor 3/4 fl. oz. 25% emulsifiable concentrate*										
Total shoots/tree	9	16	9	12	11	12	7	21	10	7
Infested shoots/tree	4	13	8	12	3	9	2	16	1	0
DDT 2¼ oz. 75% wettable powder*										
Total shoots/tree	22	30	36	41	5	14	16	13	15	8
Infested shoots/tree	0	0	0	2	0	0	1	0	0	0
Dieldrin 3 oz. 50% wettable powder*										
Total shoots/tree	7	38	50	18	7	14	21	20	7	21
Infested shoots/tree	6	22	30	10	6	10	3	6	0	10
Parathion 1½ oz. 15% wettable powder*										
Total shoots/tree	21	9	11	33	35	25	25	10	22	14
Infested shoots/tree	0	0	0	1	0	6	1	0	0	2
Parathion 1½ oz. (15% w.p.) and DDT 2¼ oz. (75% w.p.)*										
Total shoots/tree	25	34	11	10	63	6	20	5	54	8
Infested shoots/tree	1	0	0	0	0	0	0	0	0	0
Untreated										
Total shoots/tree	27	39	8	40	11	21	5	15	3	10
Infested shoots/tree	19	32	7	39	6	5	0	3	0	2

* in three gallons of water

TABLE IV

INFESTATION COUNTS OF TREES TREATED WITH DOUBLE DOSAGES OF INSECTICIDES AT ROSE LAKE PLOTS
(Sprayed June 20, 1953; counted August 14, 1953)

	Plot									
	1	2	3	4	5	6	7	8	9	10
Endrin 1½ fl. oz. 25% emulsifiable concentrate*										
Total shoots/tree	18	27	21	33	30	22	19	15	26	19
Infested shoots/tree	5	27	16	33	30	22	19	12	25	19
Heptachlor 1½ fl. oz. 25% emulsifiable concentrate*										
Total shoots/tree	10	22	18	10	13	12	9	5	25	8
Infested shoots/tree	10	20	17	8	13	12	8	5	25	7
DDT 4½ oz. 75% wettable powder*										
Total shoots/tree	23	47	33	22	16	24	11	24	13	12
Infested shoots/tree	0	0	0	1	0	3	0	0	0	0
Dieldrin 6 oz. 50% wettable powder*										
Total shoots/tree	28	12	40	14	11	23	7	23	21	31
Infested shoots/tree	20	3	26	12	11	21	7	23	15	27
Parathion 3 oz. 15% wettable powder*										
Total shoots/tree	7	11	54	16	14	17	10	11	40	5
Infested shoots/tree	0	0	4	0	1	1	0	0	2	0
Untreated										
Total shoots/tree	9	5	14	12	26	20	22	14	19	2
Infested shoots/tree	8	4	14	12	26	20	22	11	19	2

* in three gallons of water

TABLE V

INFESTATION COUNTS OF TREES TREATED WITH SINGLE DOSAGES OF INSECTICIDES AT ROSE LAKE PLOTS
(Sprayed June 27, 1953; counted August 14, 1953)

	Plot									
	1	2	3	4	5	6	7	8	9	10
Endrin 3/4 fl. oz. 25% emulsifiable concentrate*										
Total shoots/tree	23	9	28	12	16	32	8	15	8	32
Infested shoots/tree	22	9	27	4	13	32	0	15	6	32
Heptachlor 3/4 fl. oz. 25% emulsifiable concentrate*										
Total shoots/tree	19	31	26	17	24	9	9	31	13	11
Infested shoots/tree	19	27	26	17	24	9	5	29	4	11
DDT 2¼ oz. 75% wettable powder*										
Total shoots/tree	23	10	26	16	10	46	21	24	12	30
Infested shoots/tree	0	0	1	0	0	0	0	0	0	0
Dieldrin 3 oz. 50% wettable powder*										
Total shoots/tree	8	21	18	16	15	17	11	35	27	17
Infested shoots/tree	3	21	16	16	15	17	10	35	25	17
Parathion 1½ oz. 15% wettable powder*										
Total shoots/tree	6	32	19	10	11	28	10	32	9	23
Infested shoots/tree	0	1	0	1	1	1	1	3	0	1
Parathion 1½ oz. (15% w.p.) and DDT 2¼ oz. (75% w.p.)*										
Total shoots/tree	15	30	17	14	16	32	7	31	4	13
Infested shoots/tree	0	0	2	0	0	4	0	4	0	3
Untreated										
Total shoots/tree	9	5	14	12	26	20	22	14	19	2
Infested shoots/tree	8	4	14	12	26	20	22	11	19	2

* in three gallons of water

TABLE VI

INFESTATION COUNTS OF TREES TREATED WITH SINGLE DOSAGES OF INSECTICIDES AT YOUNG'S PLOTS
(Sprayed June 20, 1953; counted August 15, 1953)

	Plot 1	2	3	4	5	6	7	8	9	10
Endrin 3/4 fl. oz. 25% emulsifiable concentrate*										
Total shoots/tree	10	12	12	33	21	15	15	10	61	29
Infested shoots/tree	4	6	4	28	3	12	9	5	32	4
Heptachlor 3/4 fl. oz. 25% emulsifiable concentrate*										
Total shoots/tree	33	29	18	16	21	17	16	21	21	36
Infested shoots/tree	0	25	10	4	9	13	12	9	4	4
DDT 2¼ oz. 75% wettable powder*										
Total shoots/tree	13	26	13	15	24	13	17	10	35	33
Infested shoots/tree	0	0	0	0	0	0	0	0	0	0
Dieldrin 3 oz. 50% wettable powder*										
Total shoots/tree	11	9	23	10	22	22	11	19	34	17
Infested shoots/tree	9	7	18	7	13	9	2	0	14	9
Parathion 1½ oz. 15% wettable powder*										
Total shoots/tree	23	33	27	28	31	14	7	12	16	30
Infested shoots/tree	8	7	4	5	6	0	1	0	0	0
Parathion 1½ oz. (15% w.p.) and DDT 2¼ oz. (75% w.p.)**										
Total shoots/tree	6	16	11	8	15	13	13	11	23	38
Infested shoots/tree	0	0	0	0	0	0	0	0	0	0
Untreated										
Total shoots/tree	30	20	30	22	19	16	14	21	20	12
Infested shoots/tree	8	16	19	16	12	3	9	7	0	0

* in three gallons of water
** in three gallons of water; sprayed June 27, 1953

TABLE VII

INFESTATION COUNTS OF TREES TREATED WITH DOUBLE DOSAGES OF INSECTICIDES AT YOUNG'S PLOTS
(Sprayed June 20, 1953; counted August 15, 1953)

	Plot									
	1	2	3	4	5	6	7	8	9	10
Endrin 1½ fl. oz. 25% emulsifiable concentrate*										
Total shoots/tree	17	23	15	19	29	19	20	11	25	25
Infested shoots/tree	10	7	0	12	2	9	2	2	5	1
Heptachlor 1½ fl. oz. 25% emulsifiable concentrate*										
Total shoots/tree	12	21	12	11	27	24	16	12	33	15
Infested shoots/tree	3	21	4	5	8	10	0	12	9	5
DDT 4½ oz. 75% wettable powder*										
Total shoots/tree	9	23	29	20	13	18	13	13	34	20
Infested shoots/tree	0	0	3	0	0	0	0	0	0	0
Dieldrin 6 oz. 50% wettable powder*										
Total shoots/tree	37	31	16	19	7	20	10	16	18	37
Infested shoots/tree	0	16	1	8	0	8	0	2	5	2
Parathion 3 oz. 15% wettable powder*										
Total shoots/tree	45	29	26	15	27	8	11	9	56	40
Infested shoots/tree	0	0	0	0	1	0	0	0	0	0
Untreated										
Total shoots/tree	13	20	30	22	19	16	14	21	20	12
Infested shoots/tree	8	16	19	16	12	3	9	7	0	0

*** in three gallons of water**

TABLE VIII

PER CENT INFESTED SHOOTS IN RED CEDAR PLOTS
(Sprayed June 20, 1953; counted August 15, 1953)

Plot	Single dosages					Untreated
	Endrin	Heptachlor	DDT	Dieldrin	Parathion	
1	93	86	22	78	5	70
2	94	75	0	92	10	82
3	56	44	5	30	0	88
4	94	93	0	100	0	98
5	100	57	0	50	0	58
6	50	64	0	40	0	23
7	0	0	0	0	0	0
8	0	30	0	56	0	20
9	0	55	0	0	0	0
10	69	40	0	0	6	20
Average	55.6	53.4	2.8	44.6	2.2	45.8
Reduction from check	0.0	0.0	93.9	2.4	95.2	

TABLE IX

PER CENT INFESTED SHOOTS IN RED CEDAR PLOTS
(Sprayed June 27, 1953; counted August 15, 1953)

Plot	Single dosages						
	Endrin	Heptachlor	DDT	Dieldrin	Parathion	DDT and Parathion	Untreated
1	62	45	0	86	0	4	70
2	65	81	0	58	0	0	82
3	64	89	0	60	0	0	88
4	64	100	5	56	3	0	98
5	81	27	0	86	0	0	58
6	24	75	0	71	24	0	23
7	64	28	6	14	4	0	0
8	0	76	0	30	0	0	20
9	0	10	0	0	0	0	0
10	38	0	0	48	14	0	20
Average	46.2	52.6	1.1	50.9	4.4	.4	45.8
Reduction from check	0.0	0.0	97.6	0.0	90.4	99.1	

TABLE X

PER CENT INFESTED SHOOTS IN ROSE LAKE PLOTS
(Sprayed June 20, 1953; counted August 14, 1953)

Plot	Double dosages					
	Endrin	Heptachlor	DDT	Dieldrin	Parathion	Untreated
1	28	100	0	71	0	89
2	100	91	0	25	0	80
3	76	94	0	65	7	100
4	100	80	5	86	0	100
5	100	100	0	100	7	100
6	100	100	13	91	6	100
7	100	89	0	100	0	100
8	80	100	0	100	0	79
9	95	100	0	71	5	100
10	100	88	0	87	0	100
Average	87.9	94.2	1.8	79.6	2.5	94.7
Reduction from check	7.2	.5	98.1	14.9	97.4	

TABLE XI

PER CENT INFESTED SHOOTS IN ROSE LAKE PLOTS
(Sprayed June 27, 1953; counted August 14, 1953)

Plot	Single dosages						Untreated
	Endrin	Heptachlor	DDT	Dieldrin	Parathion	DDT and Parathion	
1	95	100	0	57	0	0	89
2	100	87	0	100	3	0	80
3	96	100	4	89	0	11	100
4	33	100	0	100	10	0	100
5	81	100	0	100	9	0	100
6	100	100	0	100	4	12	100
7	0	56	0	90	10	0	100
8	100	94	0	100	9	8	79
9	76	75	0	92	0	0	100
10	100	100	0	100	4	23	100
Average	78.0	91.2	.4	92.8	4.9	5.4	94.7
Reduction from check	17.6	3.7	99.2	2.0	95.1	94.6	

TABLE XII

PER CENT INFESTED SHOOTS IN YOUNG'S PLOTS
(Sprayed June 20, 1953; counted August 15, 1953)

Plot	Single dosages						
	Endrin	Heptachlor	DDT	Dieldrin	Parathion	*DDT and Parathion	Untreated
1	40	0	0	82	35	0	61
2	50	86	0	78	21	0	80
3	33	56	0	78	15	0	63
4	85	25	0	70	18	0	73
5	14	43	0	59	20	0	64
6	80	76	0	41	0	0	19
7	60	75	0	18	14	0	64
8	50	42	0	0	0	0	33
9	52	19	0	44	0	0	0
10	14	11	0	53	0	0	0
Average	47.8	43.4	0.0	52.3	12.3	0.0	45.7
Reduction from check	0.0	5.0	100.0	0.0	73.9	100.0	

* sprayed June 27, 1953; counted August 15, 1953.

TABLE XIII

PER CENT INFESTED SHOOTS IN YOUNG'S PLOTS
(Sprayed June 20, 1953; counted August 15, 1953)

Plot	Double dosages					
	Endrin	Heptachlor	DDT	Dieldrin	Parathion	Untreated
1	58	25	0	0	0	61
2	30	100	0	51	0	80
3	0	33	10	6	0	63
4	63	45	0	42	0	73
5	7	30	0	0	4	64
6	47	42	0	40	0	19
7	10	0	0	0	0	64
8	18	100	0	13	0	33
9	20	27	0	18	0	0
10	4	33	0	5	0	0
Average	25.7	43.5	1.0	17.5	.4	45.7
Reduction from check	43.8	4.8	97.8	61.7	99.2	

TABLE XIV

COMPARISON OF SINGLE DOSAGES OF INSECTICIDES AT TWO DIFFERENT SPRAY DATES

	Average per cent of infestation						
	Endrin	Heptachlor	DDT	Dieldrin	Parathion	DDT and Parathion	Untreated
Red Cedar June 20	55.6	53.4	2.8	44.6	2.2		45.8
Young's June 20	47.8	43.4	0.0	52.3	12.3		45.7
Red Cedar June 27	46.2	52.6	1.1	50.9	4.4	.4	45.8
Young's June 27						0.0	45.7
Rose Lake June 27	78.0	91.2	.4	92.8	4.9	5.4	94.7
Average reduction from check	4.4	2.2	97.8	1.2	88.4	97.8	

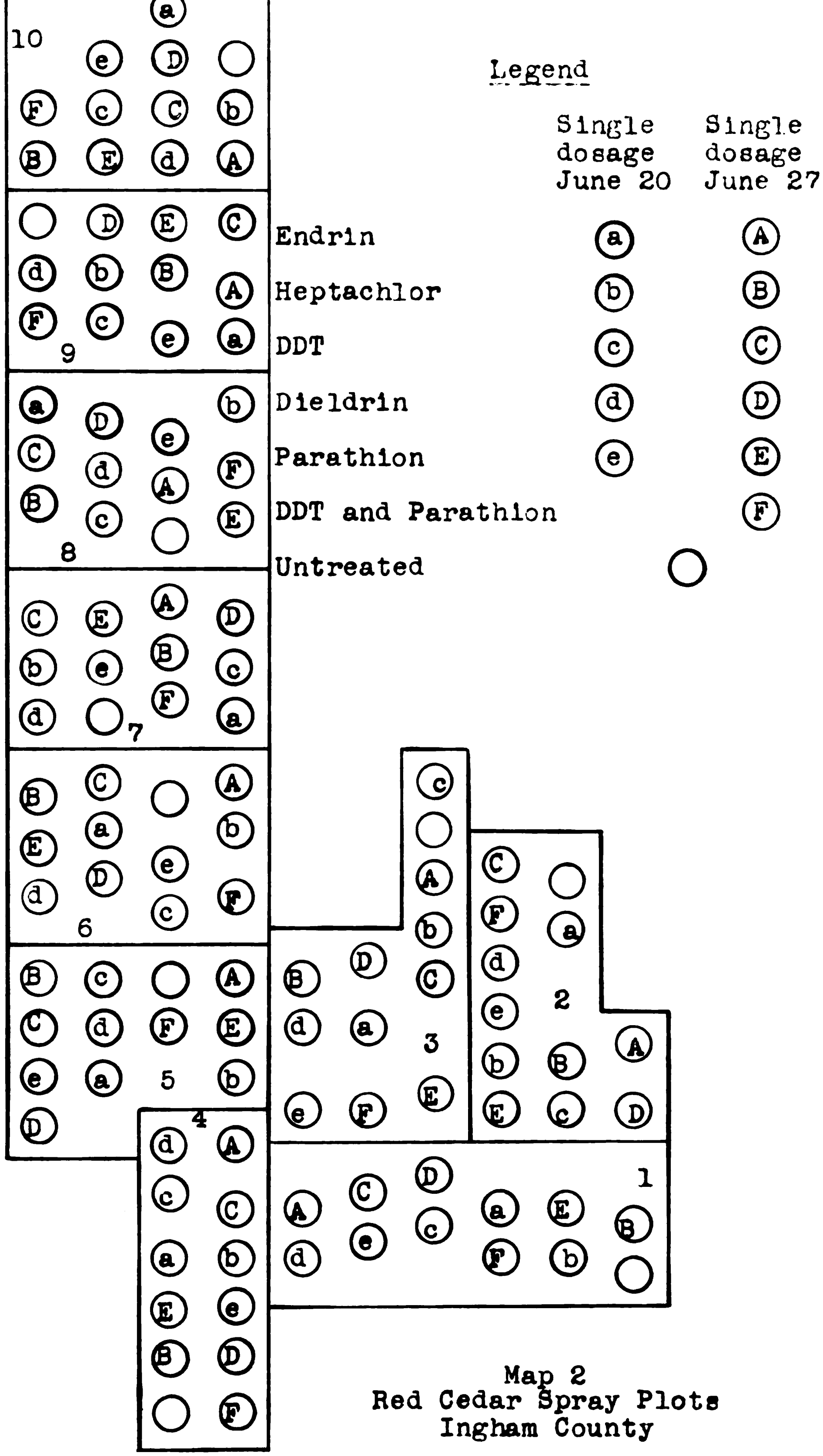
TABLE XV

COMPARISON OF DOUBLE DOSAGES OF INSECTICIDES HAVING THE SAME SPRAY DATES

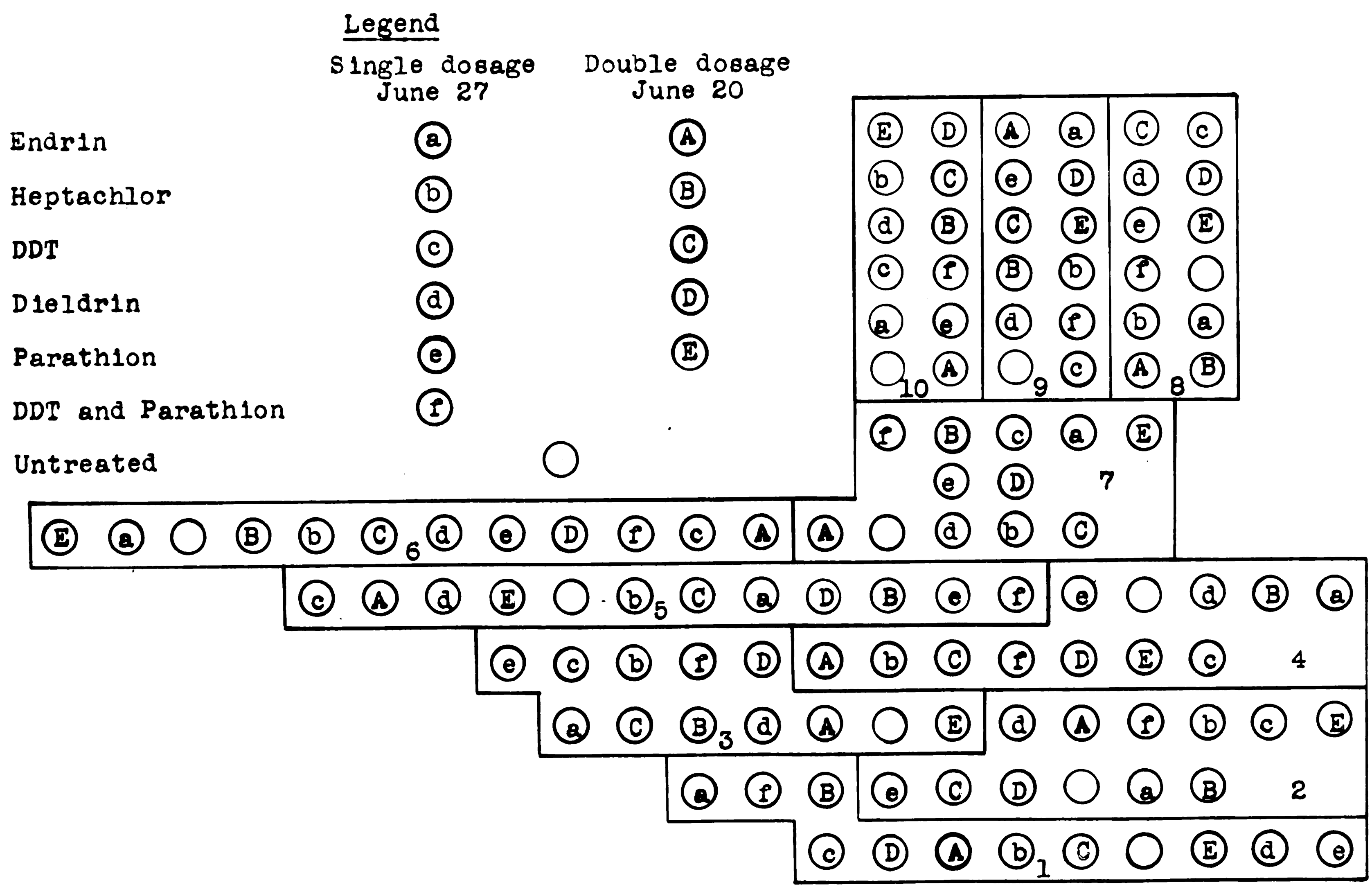
	Average per cent of infestation					
	Endrin	Heptachlor	DDT	Dieldrin	Parathion	Untreated
Rose Lake June 20	87.9	94.2	1.8	79.6	2.5	94.7
Young's June 20	25.7	43.5	1.0	17.5	.4	45.7
Average reduction from check	25.5	2.7	98.0	38.8	98.2	

1. High infestation area in southern half of lower peninsula, where airplane spraying was done.
2. Location of Red Cedar, Rose Lake and Young's plots.
3. High infestation area in southern half of lower peninsula.
4. Detroit, Ann Arbor and Monroe area where pine shoot moth was first reported in Michigan in 1930.
5. High infestation area in northern part of lower peninsula.
6. High infestation area in northern part of lower peninsula.
7. High infestation area in northern part of lower peninsula.

Map 1. Pine shoot moth distribution in Michigan, 1953



Map 2
Red Cedar Spray Plots
Ingham County



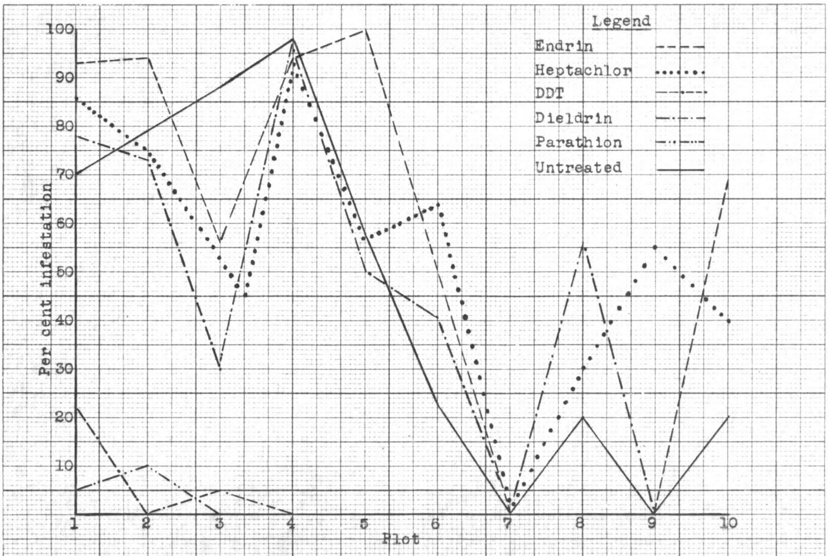
Map 3. Rose Lake Spray Plots, Clinton County

Legend

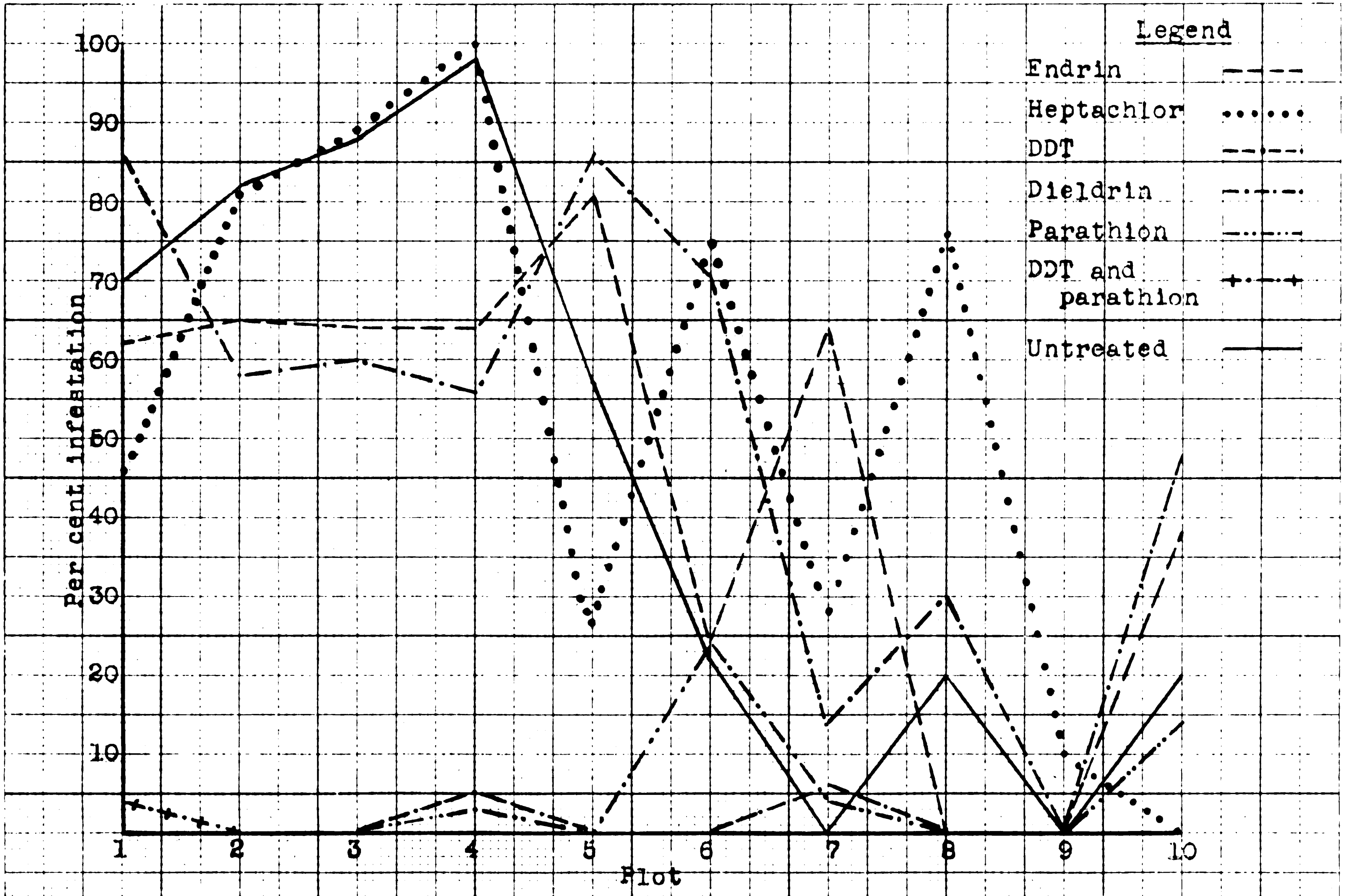
	Single dosage June 20	Single dosage June 27	Double dosage June 20
Endrin	(a)		(A)
Heptachlor	(b)		(B)
DDT	(c)		(C)
Dieldrin	(d)		(D)
Parathion	(e)		(E)
DDT and Parathion		(f)	
Untreated	○		

C	e	a	d	c	B	A	f	C	○
A	b	d	A	f	D	d	c	a	f
c	B	c	C	a	A	b	E	b	c
D	A	D	E	B	f	E	B	○	E
a	d	C	○	b	d	a	a	d	A
E	f	E	c	e	c	C	D	e	d
e	○	B	b	D	E	○	b	E	D
b	a	f	f	d	C	B	A	B	e
d	D	e	a	A	e	D	○	f	B
B	C	b	D	C	○	c	e	D	b
○	c	○	B	E	b	e	C	c	a
f	E	A	e	○	a	f	d	A	C
1	2	3	4	5	6	7	8	9	10

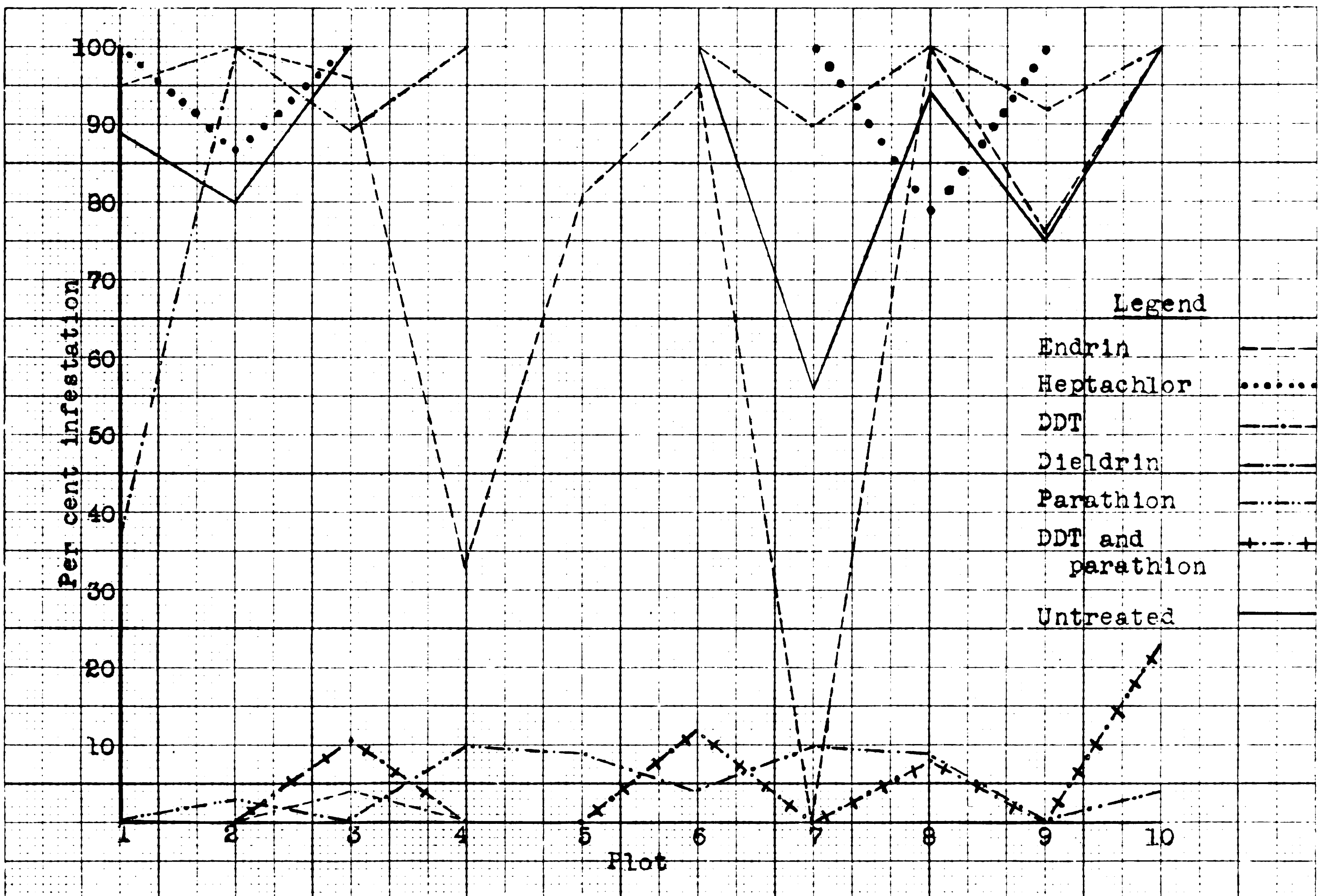
Map 4. Young's Spray Plots, Shiawassee County



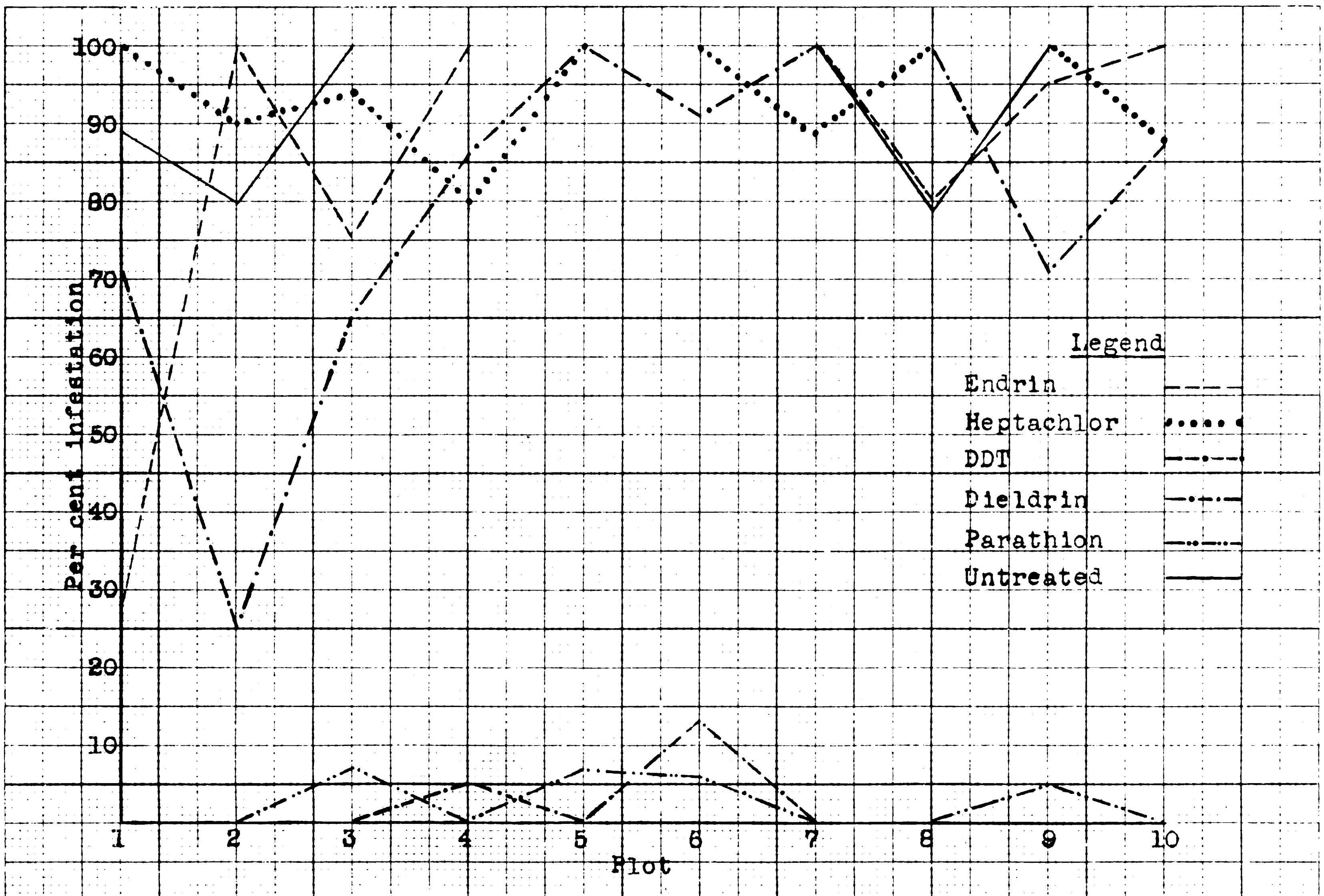
Graph 1. Per cent infestation Red Cedar Plots (single dosage, sprayed June 20, 1953)



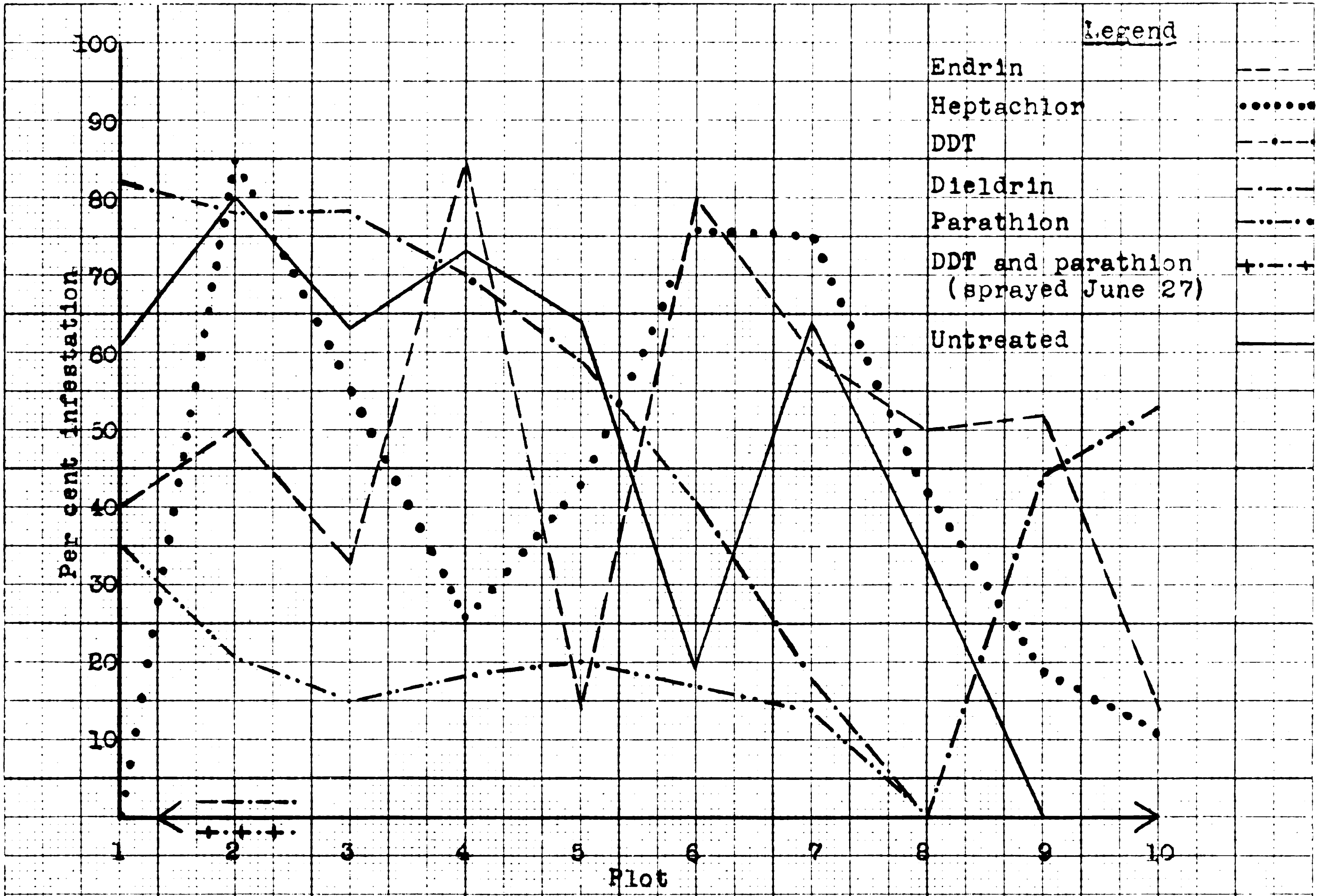
Graph 2. Per cent infestation Red Cedar Plots (single dosage, sprayed June 27, 1953)



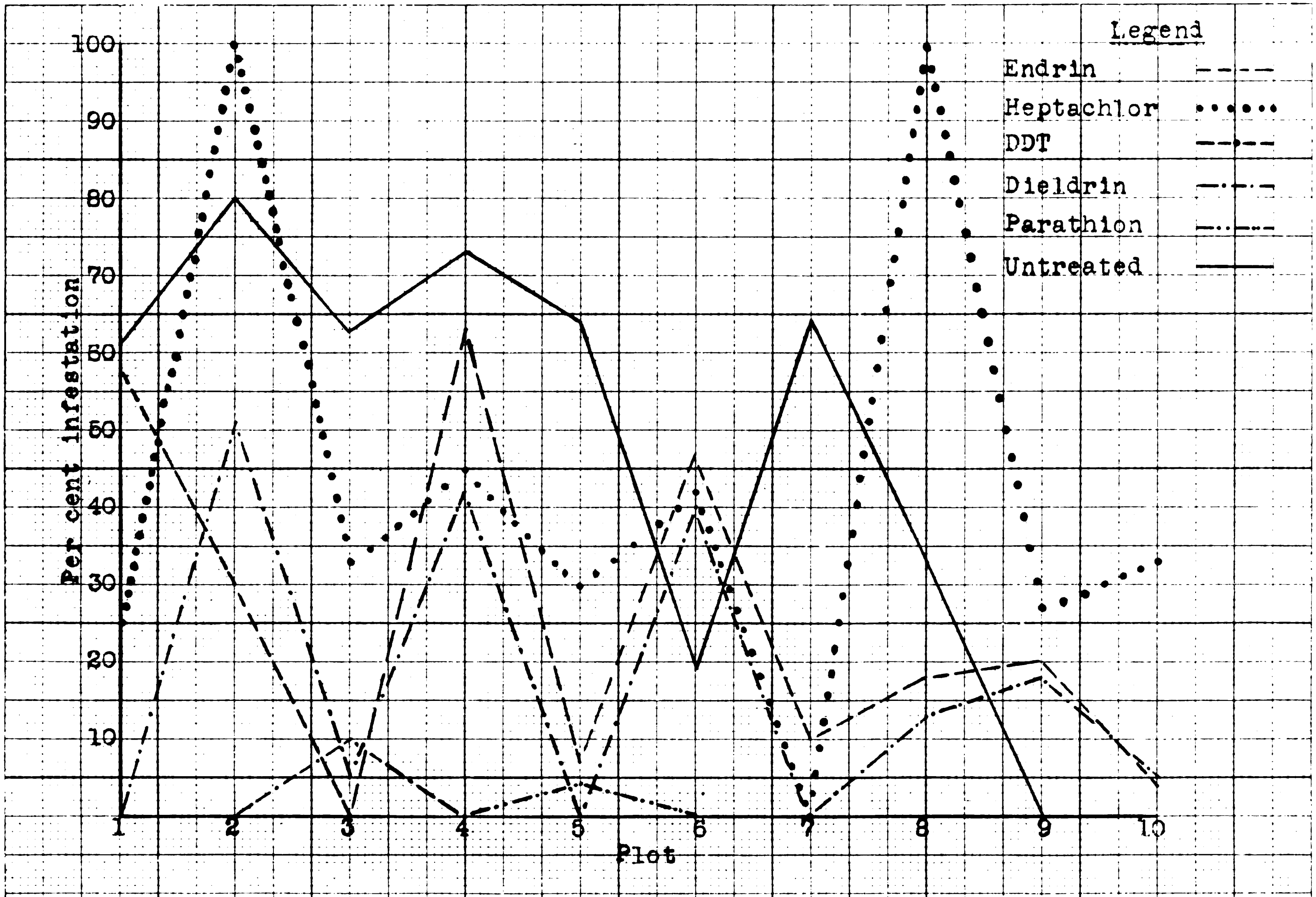
Graph 3. Per cent infestation Rose Lake Plots (single dosage, sprayed June 27, 1953)



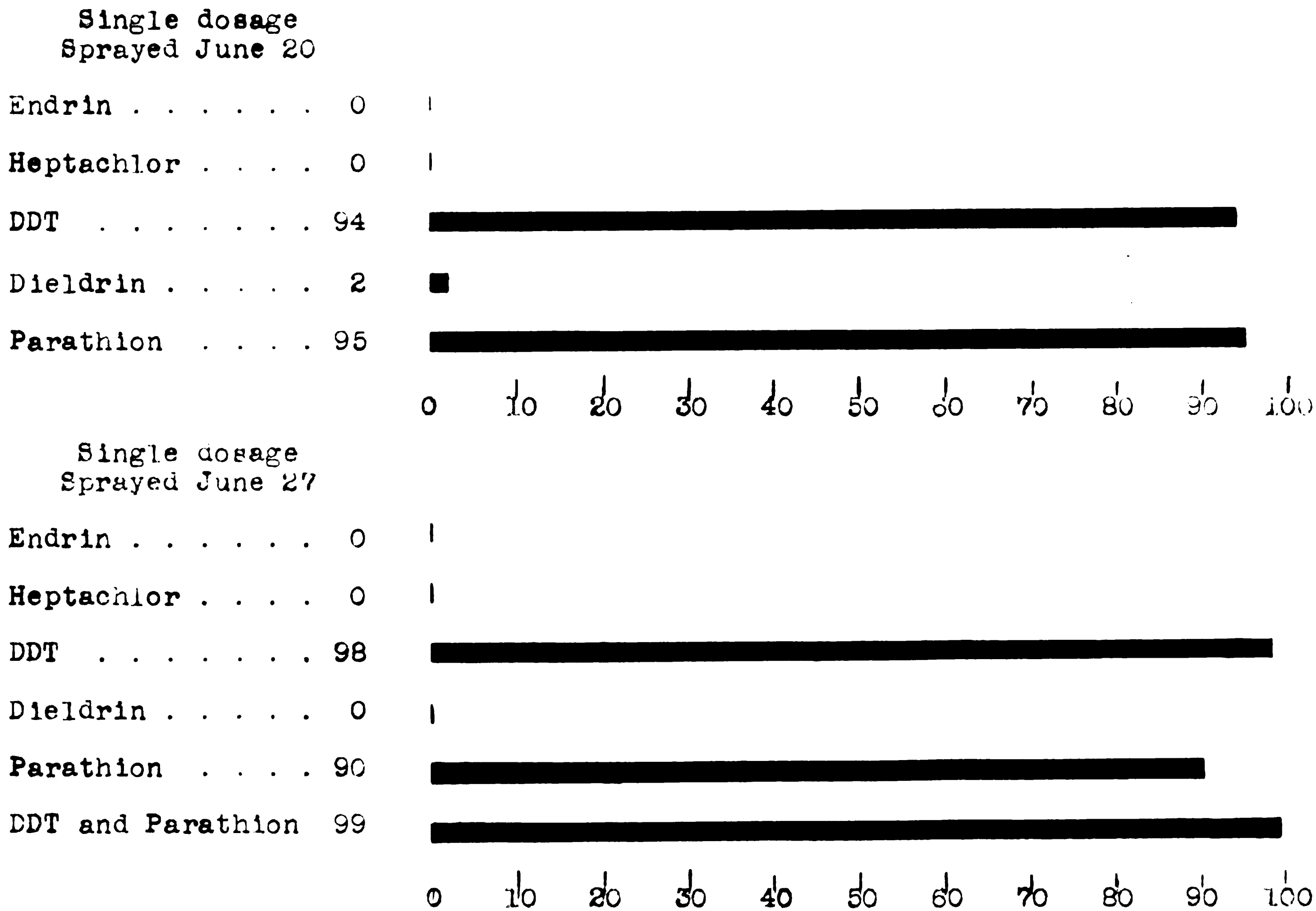
Graph 4. Per cent infestation Rose Lake Plots (double dosage, sprayed June 20, 1953)



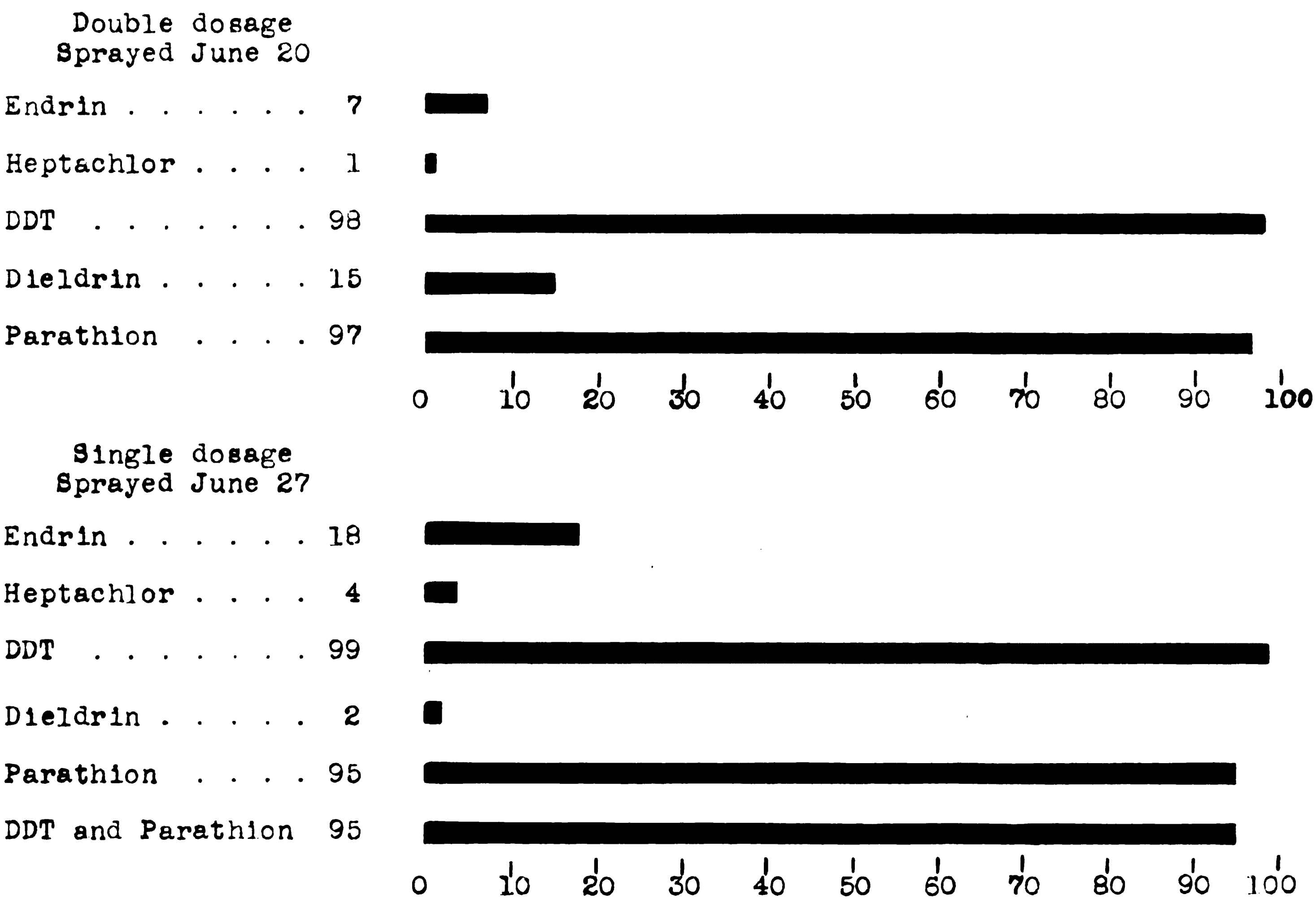
Graph 5. Per cent infestation Young's Plots (single dosage, sprayed June 20, 1953)



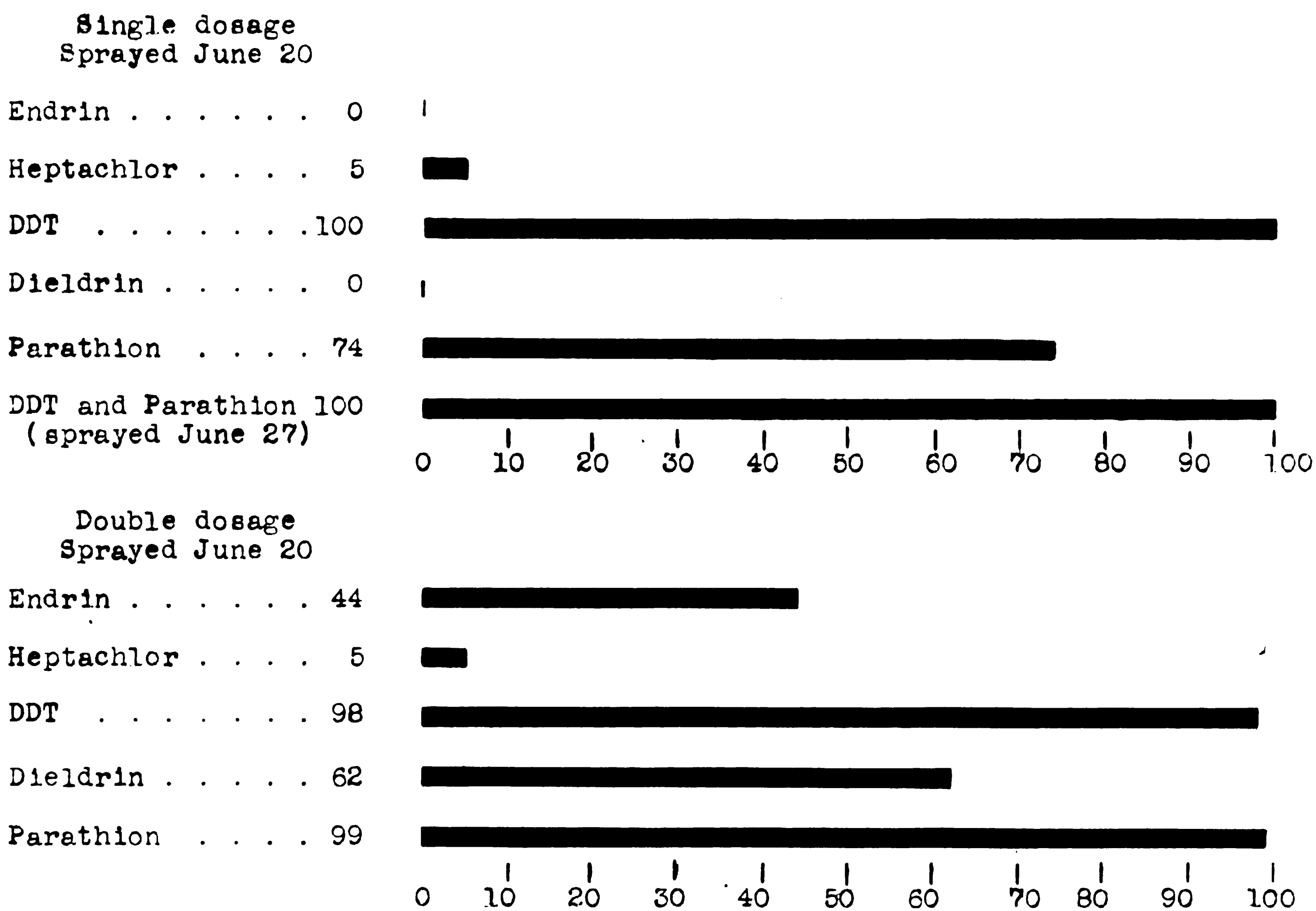
Graph 6. Per cent infestation Young's Plots (double dosage, sprayed June 20, 1953)



Graph 7. Per cent reduction of infestation in Red Cedar Plots



Graph 8. Per cent reduction of infestation in Rose Lake Plots



Graph 9. Per cent reduction of infestation in Young's Plots

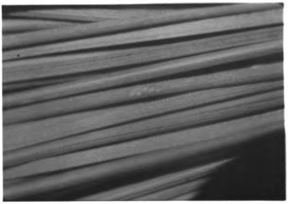


Plate 1. Eggs on needles of red pine

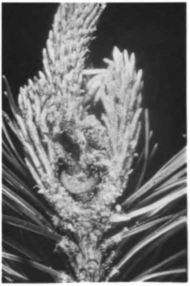


Plate 2. Larva of R. buoliana inside bud of red pine

Plate 3. Pupal case extruding from red pine shoot

Plate 4. Characteristic appearance of red pines infested with *R. buoliana*

Plate 5. "Posthorn" condition of terminal shoot on red pine