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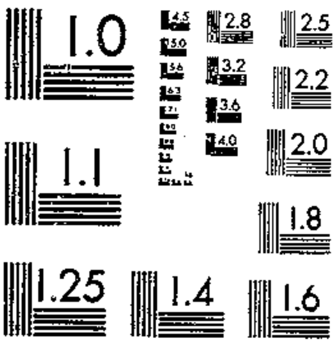

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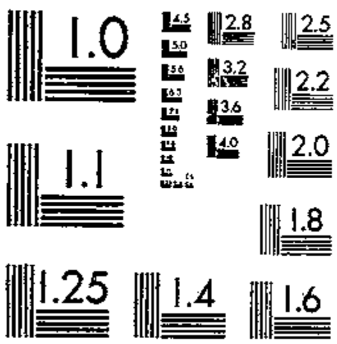

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Field Studies of Insecticides Used To Control Cabbage Caterpillars in the South[1]

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United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, in Cooperation With the Agricultural Experiment Stations of Louisiana and South Carolina

CONTENTS

INTRODUCTION

In those parts of the South where intensive and continuous production of cabbage is practiced year after year the problem of poisonous residues following applications of insecticides has at times been especially acute. Normally the caterpillars that feed on the leaves of this plant (fig. 1), including the cabbage looper (*Autographa brassicae* (Riley)), the diamondback moth (*Plutella maculipennis* (Curt.)), the imported cabbageworm (*Pieris rapae* (L.)), and others, attack it in sufficient numbers to cause damage each year (fig. 4, *A*). Occasionally they appear in outbreak numbers at the time the crop is being harvested and must be controlled when there is no opportunity for the natural removal of spray residues. In view of this situation a series of experiments was initiated so that ultimately control recommendations especially applicable to conditions in the South which would eliminate the residue hazard, might be formulated.

[1] Received for publication December 11, 1940.

[2] W. J. Reid, Jr., and Chas. E. Smith were in direct charge of the investigations at Charleston, S. C., and Baton Rouge, La., respectively, assisted by C. O. Bare and P. K. Harrison. Acknowledgments are made to C. F. Stahl, who had general supervision of the cabbage insect work in the South beginning with June 1934.

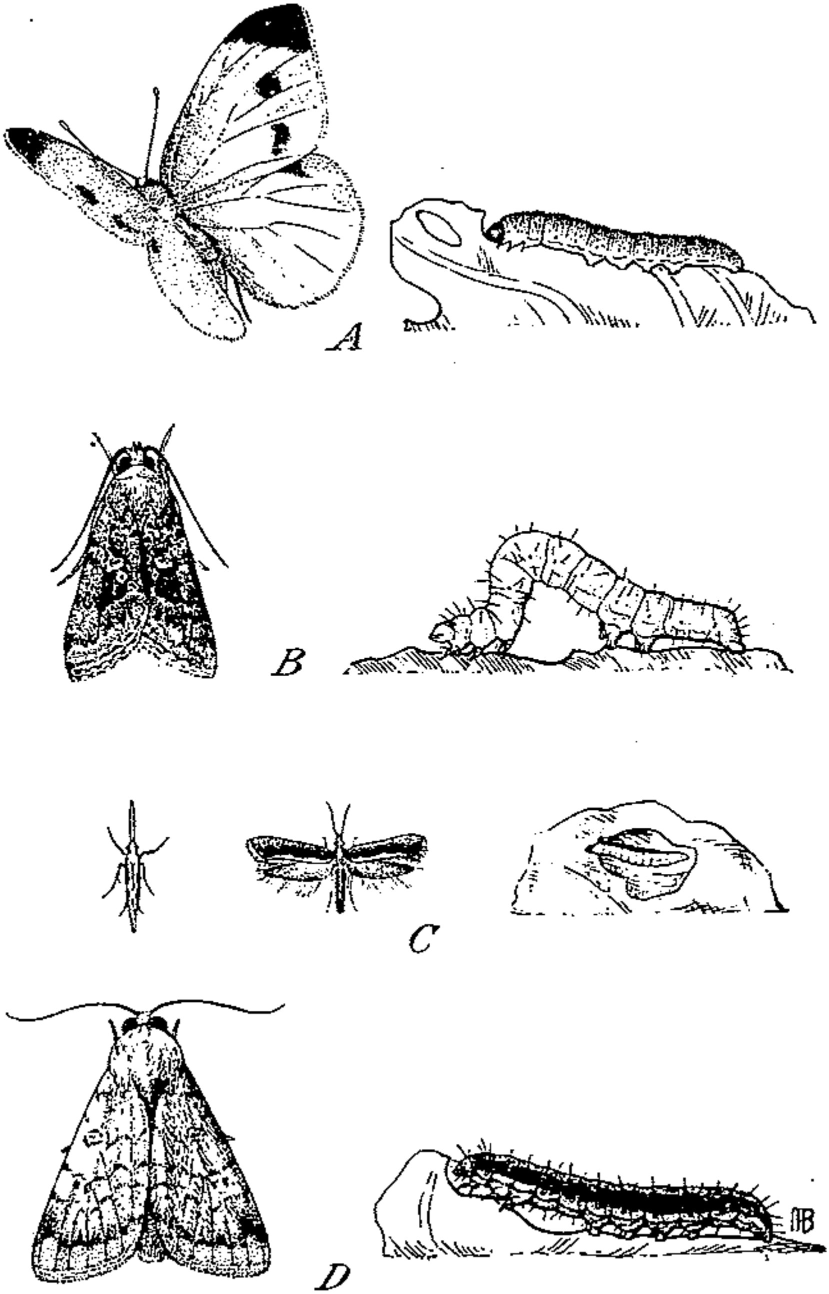

FIGURE 1.—Adults and larvae of cabbage caterpillars: *A*, The imported cabbageworm (*Pieris rapae*); *B*, the cabbage looper (*Autographa brassicae*); *C*, the diamondback moth (*Plutella maculipennis*); *D*, the corn earworm (*Heliothis armigera*). Slightly enlarged.

The first step was a study of the limitations on the use of arsenicals on cabbage being grown in the South. Results of this work have been published.[3] In this study it was demonstrated that arsenicals at the strengths tested should not be used on cabbage intended for marketing as U. S. Grade No. 1, which ordinarily bears four loose outer leaves, after the heads begin to form. It was further demonstrated that the inclusion of more than four loose outer leaves on the marketed product increases the length of time before harvest in which it is unsafe to use arsenicals and makes it dangerous to use such materials after the seedling stage. In other words, arsenicals should not be applied at any time on that portion of the plant which is to be marketed or consumed as food.

As cabbage caterpillars [4] are often present on the crop during the period when it is unsafe to use arsenicals, it was necessary to find a satisfactory substitute that would kill them and not leave a harmful residue. With this in view, field experiments were conducted to determine the comparative effects of the least objectionable arsenicals and other available materials considered nontoxic to man but known to be toxic to certain insects, that might prove satisfactory in controlling caterpillars on the plants. The ultimate objective of these comparisons was to make possible a more intelligent study of the practical use of the more promising of such materials. These investigations were in progress from the spring of 1933 through the spring of 1935, and the results are made the subject of this bulletin.

The experiments were conducted as a cooperative project between the field laboratories of the Bureau of Entomology and Plant Quarantine at Baton Rouge and at Charleston [5] and the Agricultural Experiment Stations of Louisiana and South Carolina, the Charleston laboratory of the Bureau being located at the South Carolina Truck Experiment Station and the Baton Rouge laboratory at the Louisiana Agricultural Experiment Station.

SCOPE OF THE WORK

In the search for insecticides that are nontoxic to man, three were found available that showed promise as possible substitutes for arsenicals. Two of them, ground pyrethrum flowers and ground hellebore root, had for many years been reputed to be of value in controlling cabbage caterpillars. The third, ground derris root, a relatively new rotenone-containing insecticide, was known to be toxic to many insects including cabbage caterpillars. Very little information was available concerning efficient dilutions of any of these materials or their relative effectiveness, as compared with arsenicals, for controlling the caterpillars under field conditions.

Since promising insecticides were already available, it was not deemed necessary to conduct laboratory tests in search of new ones until these known ones had been thoroughly tested under field conditions. Therefore the experiments were confined to the determination

[3] WHITE, W. H. A SUMMARY OF STUDIES ON ARSENICAL SUBSTITUTES FOR CABBAGE WORM CONTROL ON CABBAGE AND LIMITATIONS ON ARSENICAL TREATMENTS. Jour. Econ. Ent. 28: 607–609. 1935.
SMITH, CHAS. E., REID, W. J., JR., HARRISON, P. K., and BARE, C. O. A STUDY OF ARSENICAL DUSTING OF CABBAGE IN RELATION TO POISON RESIDUES. U. S. Dept. Agr. Cir. 411, 8 pp., illus. 1937.

[4] The popular term "cabbage caterpillars" will be understood as including all the species of caterpillars attacking the cabbage leaves.

[5] Certain phases connected with the preliminary work were considered in experiments conducted at Chadbourn, N. C.

of the comparative effectiveness of the insecticides as reflected by the numbers of caterpillars present in field plots of cabbage after different treatments.

During the early part of the investigations it was necessary to determine the most promising diluents and dilutions for the various materials used as well as the rates of application, and the influence of varying weather conditions on the application and effect of the materials also had to be considered. For these reasons much of the early work was more or less preliminary, and the results cannot very well be combined with those obtained in the more intensive investigations that followed. This preliminary work was important, however, from the standpoint of the investigation as a whole, and a discussion of it will be included.

CULTURAL PRACTICES

As far as possible the methods of culture considered to be best adapted to the locality were employed at each laboratory throughout the investigation. Most of the experimental plantings were grown during the usual periods of commercial production, except in some instances when, after severe winters, the spring crop was set slightly later in order the better to insure an adequate insect population.

In most cases the variety of cabbage generally grown in the area was used in the experimental plantings at each laboratory. In no instance was a variety planted which was not adapted to the locality. Unless indicated otherwise, the Charleston Wakefield variety was employed at Charleston, S. C., and Chadbourn, N. C., and the Copenhagen Market variety at Baton Rouge, La.

The production period for cabbage in the South usually extends from late in the summer through the winter and up to the end of the spring months, and during this time the crop is grown more or less continuously. It is a rather common practice to make two general plantings, and these plantings are referred to in this bulletin as the fall and spring crops. An intermediate planting started late in the fall and harvested late in the winter has been considered as a winter crop. Insect populations are usually very light in midwinter, and for this reason practically all the experimental work was confined to fall and spring plantings.

INSECTS INVOLVED

Throughout the entire series of experiments only those species of caterpillars that are normally of economic importance in the winter-cabbage-growing areas of the South were taken into consideration. Certain species appeared to predominate during certain seasons, and frequently the species predominating in one locality for a given season was not the same as that predominating in the other localities. During one or more of the seasons included in these investigations the species that appeared in sufficient numbers in each of the three localities to make possible the accumulation of reliable data were the cabbage looper (*Autographa brassicae* (Riley)), the diamondback moth (*Plutella maculipennis* (Curtis)), the imported cabbageworm (*Pieris rapae* (L.)), and several species of the Agrotinae.[6]

[6] In this bulletin several noctuids comprised largely of three species, viz, the black cutworm (*Agrotis ypsilon* (Rott.)), the granulate cutworm (*Feltia annexa* (Treit.)), and the corn earworm (*Heliothis armigera* (Hbn.)), will be considered as a group and referred to by their subfamily name, Agrotinae.

During the fall months the cabbage looper and the Agrotinae were the most abundant species at all three localities. Although not so numerous as the cabbage looper, the Agrotinae were destructive to cabbage during certain fall seasons at Baton Rouge and at Charleston. The imported cabbageworm appeared late in the season on fall crops at Baton Rouge and Charleston, and the diamondback moth was present in small numbers at both localities during this period. The cabbage webworm (*Hellula undalis* (F.)) also is often injurious to fall-crop plantings at each location, but is a pest chiefly of seedling plants, and it was not present in large numbers at the time the studies discussed herein were made.

On the spring crops the diamondback moth usually was the most prevalent species in all three localities, this being especially true at Charleston. The cabbage looper and the imported cabbageworm also were abundant on spring crops at the three locations, the last-named species being the most destructive of the caterpillars attacking spring cabbage at Baton Rouge.

MATERIALS COMPARED

The dust form of insecticides has been most used for the control of cabbage caterpillars in the areas included in these investigations. For this reason practically all comparisons were made between materials applied as dusts. Those dilutions that appeared most logical on the basis of past experience were first tried, as well as the materials in their original concentrations in cases where little or no information concerning them was available. As the studies progressed the use of materials and dilutions showing little or no effectiveness was discontinued, and desirable changes were made in the dilutions of those showing most promise. Diluents were selected primarily on the basis of cost and availability, but some consideration was given to physical and chemical compositions in so far as it was thought that they might affect the efficiency of the toxic elements or the practical use of the dusts.

Inasmuch as the main objective of the experiments was to study the effect of toxic agents that were not considered particularly harmful to the consumer, special emphasis was placed on the performance of powdered derris root, hellebore, and powdered pyrethrum flowers. Paris green, calcium arsenate, and cryolite, considered as the least objectionable of the inorganic insecticides, were included in practically all the tests so that their efficiencies might be compared with those of the possible substitutes. Where special combinations and other materials were used to a limited extent, particularly in the early experiments, mention is made of them in discussion of the experiments.

A special effort was made to procure fresh materials for all tests. They were obtained from reliable firms and subjected to analysis by the Insecticide Division of the Bureau of Chemistry and Soils [7] before being used. The dilutions of derris-root powder were based on rotenone content, those of pyrethrum flowers on pyrethrin I content, and those of the other materials on parts by weight. Future references to specific dilutions will be expressed in terms of these basic ingredients or as parts by weight.

[7] Now the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine.

EXPERIMENTAL METHODS

The accuracy of experiments designed to show comparisons between insecticides used under field conditions is primarily dependent upon the refinement of methods used in conducting the work and in treating the data obtained. Throughout the course of these experiments an effort has been made to improve the technique employed so as to increase the significance of the results. Even with the best methods available and the exercise of extreme care, it is recognized that any measurements obtained are subject to the qualification that differences

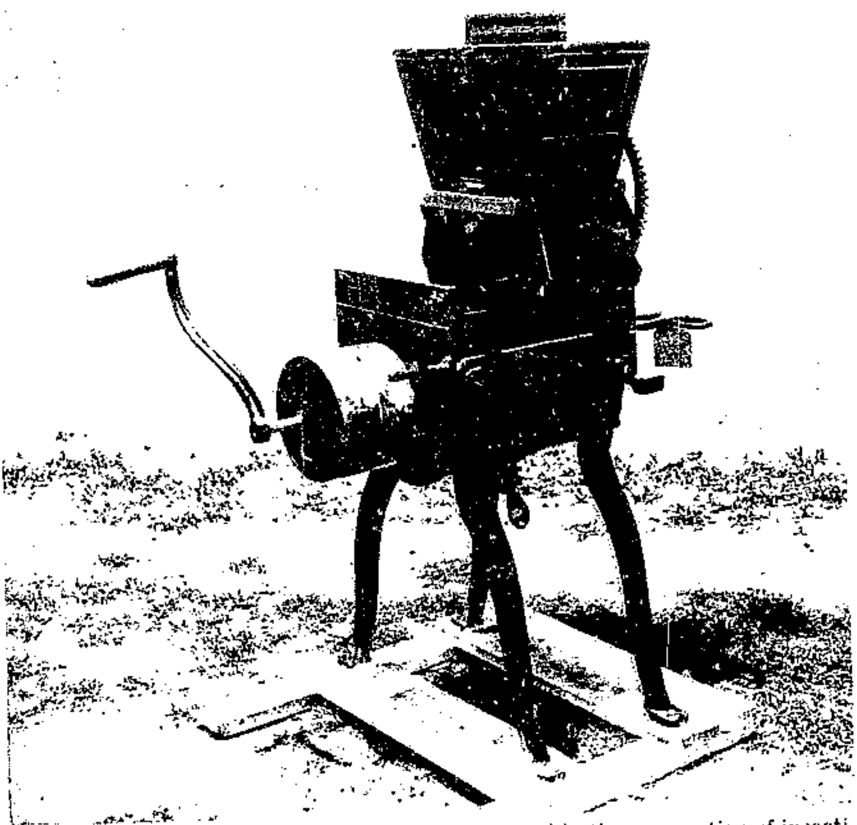

FIGURE 2.—Type of sifting and mixing machine used in the preparation of insecticide dusts.

might, and probably do, exist which could not be measured under the conditions encountered. On the other hand, differences that are clearly demonstrated may be less significant from the practical standpoint than the data would indicate.

In all the experiments use was made of replicated plots, and in most cases some degree of randomization was employed. Attention was given to the size of plots as well as their shape and protection from treatments on adjacent plots. The question of sampling was studied, and improvements were made in the method of sampling as the work progressed. In all except several of the earliest experiments, in which the caterpillar populations were counted on a limited number of the same plants before and after the applications, the results were based on the caterpillar populations surviving after the different applications.

The materials were mixed with the diluents not more than 24 hours before the applications were made. Mixing was done in a sifting and mixing machine (fig. 2) of about 50 pounds' capacity, operated for a period of 5 minutes. Applications were made by means of rotary

FIGURE 3.—Type of rotary, hand dust gun used in application of insecticides.

hand dust guns (fig. 3), with one trip per row before the plants began to head and two trips per row, one from each side, thereafter. Except in the preliminary experiments, the materials were usually applied late in the afternoon or early in the evening and when the plants were either dry or were slightly moist with dew. In most cases from 15 to 20 pounds were applied per acre, the quantities being determined by weighing the dust guns before and after each application.

INITIAL STUDIES

The experiments conducted from the spring of 1933 through the spring of 1934 were largely preliminary. Although a certain amount of cooperation existed between the laboratories, only parts of any one experiment were replicated by seasons or by localities. Any attempt to combine the results of these with later experiments, which were carefully replicated, would be undesirable. To avoid confusion, therefore, the results of this initial work will be presented separately. Some of the information has been published [5] in mimeographed form.

SPRING OF 1933

During the spring of 1933 four field experiments were conducted at Baton Rouge, La., two at Charleston, S. C., and three at Chadbourn, N. C. In one or more of these paris green and lime 1–10; calcium arsenate; and hellebore, pyrethrum, and derris, both diluted with tobacco dust and dusting sulfur either alone or in combination, and undiluted, were used. The results of these experiments demonstrated that pyrethrum, derris, or hellebore, diluted with equal parts of tobacco dust or sulfur, resulted in practically as high a mortality of caterpillars as when used at full strength. Hellebore was distinctly inferior to the other two organic materials in all the trials and was eliminated from further experiments. Both pyrethrum and derris, used separately, compared favorably with paris green and lime 1–10 and with undiluted calcium arsenate. They also compared favorably even when either was diluted with several parts of tobacco dust or dusting sulfur. Some indications were obtained that both tobacco dust and sulfur might have some insecticidal effect on one or more of the species.

In several of these experiments a comparison was made of the relative effectiveness of pyrethrum and derris when applied at different times of the day. The results obtained indicated that pyrethrum was more effective when applied late in the afternoon than when applied during the forenoon, but that there was little or no difference between the effectiveness of the forenoon and afternoon applications of derris. This eventually led to the application of all organic materials late in the afternoon. Counts of caterpillars made 6 days after the applications showed in one of the experiments that the effect of derris lasted several days, whereas that of pyrethrum was dissipated in a relatively short time under field conditions.

The cabbage looper was the most abundant species during this season at each location. There was a moderate infestation of the diamondback moth, and there were a few imported cabbageworms. As these species reacted differently toward the different insecticides, it was necessary to keep separate records for each. In some cases it was evident that the smaller larvae were more susceptible than were the larger ones and that variations in size of the larvae present in the different experiments interfered with the comparison of the results.

In the Chadbourn and Charleston experiments an attempt was made to test each material, or dilution thereof, at applications of both 10 and 15 pounds per acre. Under the conditions which prevailed, however, variations in the actual dosages were so great that it was impossible to make fair comparisons. In subsequent experiments the various dilutions of the materials were compared at approximately constant rates of application. In the second Charleston experiment records were made of yields produced on the various experimental areas, only weights of the plants being obtained, as soil conditions pre-

[5] WHITE, W. H. PROGRESS REPORT OF EXPERIMENTS ON THE CONTROL OF CABBAGE WORMS. U. S. Bur. Ent. Cir. E-309, 14 pp. 1933. [Mimeographed.]

——— RECOMMENDATIONS FOR THE CONTROL OF INSECTS ATTACKING CERTAIN VEGETABLES, SMALL FRUITS, AND TOBACCO, AND THE ELIMINATION OF HARMFUL INSECTICIDAL RESIDUES FROM THE MARKET PRODUCT. U. S. Bur. Ent. and Plant Quar. Cir. E-343, 13 pp. 1935. [Mimeographed.]

——— RECOMMENDATIONS FOR THE CONTROL OF INSECTS ATTACKING CERTAIN VEGETABLES, SMALL FRUITS, AND TOBACCO. U. S. Bur. Ent. and Plant Quar. Cir. E-376, 14 pp. 1936. [Mimeographed.]

vented the greater number of the plants from producing firm heads. The yield of the areas treated with derris, undiluted and with equal parts of diluent, was significantly greater than that of the untreated

FIGURE 1.—Caterpillar injury to cabbage: *A*, Cabbage plants injured by the feeding of caterpillars; *B*, plants protected by four applications of a dust mixture containing 1.7 percent of rotenone.

areas. Figure 1, *A*, illustrates the severity of caterpillar injury to cabbage plants receiving no treatment, compared with the condition (fig. 4, *B*) of plants dusted four times with a mixture containing 1.7 percent of rotenone prepared by mixing equal parts of derris and tobacco dust.

Of the two Charleston experiments, which were duplicates except as to the dates on which they were conducted, the one under way late in the spring had the greater caterpillar populations and was of more value to the investigation than was the one conducted during the winter and early spring months.

In these spring experiments at Charleston cloth barriers 3 feet high were erected around each plot while the dusts were being applied. As these barriers did not prevent the dusts from drifting into adjacent plots, however, their use was discontinued.

FALL OF 1933

During the fall of 1933 four experiments were conducted at Baton Rouge and one at Charleston. In these experiments, in addition to comparisons of the relative value of different insecticidal materials in reducing the populations of cabbage caterpillars, comparisons were made of the same strengths of derris and pyrethrum with different diluents, and one or more dilutions of paris green, calcium arsenate, barium fluosilicate, natural and synthetic cryolites, derris, and pyrethrum were used in one or more of the experiments. The diluents employed were lime for the arsenicals; talc, sulfur, and clay for the fluorine compounds; and talc, tobacco dust, sulfur, and clay for derris and pyrethrum.

A dosage of 15 pounds per acre per application was adopted for these experiments, as it had been indicated in previous tests that approximately this quantity would give a satisfactory coverage with the equipment in use. It had been determined also that derris and pyrethrum powders could be diluted with equal parts of a diluent without significantly decreasing their effectiveness. Consequently the Charleston experiment was designed to employ a range of dilutions from those which certainly would give satisfactory caterpillar reductions down to those which probably would not.

At Charleston the materials and dilutions consisted of paris green and lime (1–9); calcium arsenate, undiluted; barium fluosilicate and clay (1–4); natural cryolite and clay (1–2, 1–4, and 1–6); natural cryolite, clay, and sulfur (1–2–2); pyrethrum diluted with clay to contain 0.1, 0.05, and 0.025 percent of pyrethrin I; derris diluted with clay to contain 1.5, 1.0, 0.5, and 0.1 percent of rotenone; and derris diluted with clay and sulfur to contain 0.5 percent of rotenone.

In the Baton Rouge experiments the materials and dilutions employed consisted of paris green and calcium arsenate, each diluted to contain 6.67 and 5 percent of arsenic trioxide (As_2O_3) or the equivalent; synthetic cryolite and talc (1–2 and 1–3); synthetic cryolite and sulfur (1–3); barium fluosilicate and talc (1–2 and 1–3); barium fluosilicate and sulfur (1–3); derris, diluted with sulfur, or with talc, or with tobacco dust, to contain 1.0 percent and 0.5 percent of rotenone; derris diluted with a combination of sulfur and talc to contain 0.5 percent of rotenone; pyrethrum diluted with sulfur, with talc, or with tobacco dust to contain 0.15, 0.1, and 0.05 percent of pyrethrin I; and pyrethrum diluted with a combination of talc and sulfur to contain 0.075 percent of pyrethrin I.

At Baton Rouge, where this season the imported cabbageworm constituted the major portion of the population, the indications were that the derris and pyrethrum mixtures were superior to those of the inorganic materials. There were some slight differences, which may have been due to experimental error, between like dilutions of the organic materials in which different diluents were used. The diluted calcium arsenate dusts were apparently inferior to the other three inorganic materials. In the Charleston experiment, where the caterpillar population was light and consisted largely of the cabbage looper, the results were not very conclusive, but were in line with those of the preceding tests. An interesting point of this experiment, however, was the relatively greater effectiveness of the pyrethrum dusts in reducing the cabbage looper population as compared with that in some of the previous tests. In the 1933 experiment the plants were drier at the time of the applications, and this may have favored the pyrethrum treatment.

Spring of 1934

The experiments of the spring of 1934 were more complete and more closely coordinated than were those of the preceding seasons. One large experiment was conducted at each of the three laboratories. Derris and pyrethrum were diluted to give mixtures comparable to those used the previous fall and were compared with calcium arsenate, paris green, and cryolite. Since treatments additional to those at Baton Rouge were included at Charleston and Chadbourn, and since there were various other differences between the experiments in the three localities, these experiments will be discussed separately.

The Baton Rouge experiment consisted of 11 treatments, including an undusted check, which were replicated and randomized in each of 4 parallel blocks. The treatments were as follows: Derris-root powder diluted with tobacco dust to make dusts containing 0.25, 0.5, 1, and 2 percent of rotenone; pyrethrum powder diluted with tobacco dust to make dusts containing 0.025, 0.05, and 0.1 percent of pyrethrin I; paris green mixed with hydrated lime (1–9); calcium arsenate, undiluted; and synthetic cryolite mixed with dusting sulfur (1–3). The plots, one-twentieth of an acre in area, contained 8 rows 3 feet wide and 91 feet long. Three applications of the insecticides were made at intervals of 10 and 11 days. Approximately 15 pounds of the dusts was applied per acre per application.

A uniform sample, consisting of counts of the caterpillars on 50 plants per plot located in the center 4 rows, was taken from all plots 3 and 4 days after each application. To avoid using the same plants in the different counts, and also to spread the sample over as much of the plot as possible, the fourth consecutive plant was selected each time, with plants 1, 2, and 3 from the south end of the rows as the starting point in the respective counts. To obtain information on the residual value of the various treatments, an extra count was made 6 and 7 days after the first application.

The caterpillar population was recorded by species on each individual plant of a sample. The purpose of this was to compare the reaction of the different species to the different materials and dilutions, also to provide information on the distribution of the different species from plant to plant within the plots. For the four counts, including the extra count for the residual effect, the population averaged 1.7 caterpillars per plant per count. The imported cabbageworm constituted about one-half the entire population, with the cabbage looper ranking second and the larva of the diamondback moth third.

Based on the caterpillar counts, general field observations, and the statistical analyses of the data obtained in this experiment, derris, in general, gave better results than any other material used. There was no significant difference between derris (containing 1 and 2 percent of rotenone) and pyrethrum (containing 0.1 and 0.05 percent of pyrethrin I) for the control of the loopers. Derris at the dilutions above mentioned was superior to all the other materials used against the imported cabbageworm and, except for calcium arsenate, was superior to all other materials used against the larvae of the diamondback moth.

The paris green-lime mixture was inferior to the stronger mixtures of both pyrethrum and derris, but was superior to both undiluted calcium arsenate and cryolite in the case of the imported cabbageworm. It was about equal to cryolite when used against the loopers and larvae of the diamondback moth, and inferior to calcium arsenate for the latter species.

Observations on this experiment indicated that derris possesses a repelling or paralyzing effect which tends to cause the surviving larvae to cease feeding for several days, and also a residual effect that might aid in controlling the insects. In contrast to derris, pyrethrum appeared to have little or no residual effect.

Except for minor changes in 3, the Chadbourn experiment included the same 11 treatments that were used at Baton Rouge. Each treatment was replicated in each of 3 randomized blocks. An average peak infestation per plant of 7.7 loopers and 1.7 diamondback larvae developed. The results were comparable to, but less conclusive than, those obtained at Baton Rouge. This experiment also included both morning and afternoon applications of 1 dilution of each of the 5 insecticides; and, in addition, each block contained 3 rates of application—20, 30, and 40 pounds per acre—of both calcium arsenate and paris green. The caterpillars were materially reduced by all the arsenical and cryolite treatments but no one rate of application or time of application gave better results than any other for any one material.

At Charleston the five principal insecticides were diluted with clay to make dusts comparable to those used at Baton Rouge. They were compared in three randomized-block replicates. The results were less conclusive but in general substantiated those obtained at Baton Rouge. The imported cabbageworm was the most abundant species at this time, reaching an average infestation of 1.6 caterpillars per plant as compared with 0.8 looper and 0.4 larva of the diamondback moth. These estimates are somewhat low, as they are based on the infestation of the usually marketed portion of the plant. Magnesium arsenate was also used in this experiment, but it was ineffective.

The following sprays were included in the Charleston experiment: Derris-root powder, in suspension and as an extract, applied so as to give the same quantity of rotenone per acre as the 0.5-percent dust; pyrethrum powders, in suspension and as an extract, comparable to the dust containing 0.085 percent of pyrethrin I; a combination of rotenone and of pyrethrum extracts, containing one-half of the active ingredients of each of the two sprays in which these ingredients occurred separately; calcium arsenate, paris green and lime, and magnesium arsenate, each in suspension at application rates comparable to those of the dusts of each material, and cryolite in suspension at a rate comparable to that of the 1–4 dust dilution. A miscible pine oil was used as a spreading agent at a dilution of 1–400 in all the sprays. The sprays were applied throughout the day with a knapsack sprayer operating at approximately 75 pounds pressure.

The sprays compared favorably with the dusts at similar dosages, with the exception that the derris sprays were significantly inferior to the derris dusts when used against the cabbage looper. The spray suspensions were as effective as were the spray extracts. The pyrethrum suspensions appeared to be particularly effective in reducing the looper and imported cabbageworm populations.

Summary of Early Experiments

Because of imperfections in the design of the greater part of the early experiments, there being no provision for adequate measurement and control of experimental errors, it was not possible to determine accurately the relative merits of the various materials used. These preliminary trials, however, were necessary to furnish experience and information upon which to base the selection of materials, diluents, and dilutions, as well as the technique for use in more critical tests. The information from these experiments may be briefly summarized as follows: (1) Derris and pyrethrum possessed toxic effects that showed promise in reducing the cabbage caterpillar populations; (2) hellebore was relatively ineffective as a toxic agent for cabbage caterpillars; (3) both derris and pyrethrum powders in the form purchased on the market contained greater toxic strengths than were necessary and could be advantageously diluted with sulfur, tobacco dust, talc, or pulverized china clay; (4) afternoon applications of pyrethrum were more effective than morning applications; (5) calcium arsenate undiluted, paris green 1–9 with lime, cryolite 1–2 with talc, clay, or sulfur, and various dilutions of derris and pyrethrum were the materials that showed the most promise in killing cabbage caterpillars; (6) toxic effects appeared to vary to some extent according to the species of caterpillars predominating on the cabbage; (7) owing to the residual effect of derris and the arsenicals, the full effects of the insecticidal treatments could not be determined by counts made within 24 hours after dusting; (8) significant comparisons between the treatments were difficult to obtain, making it desirable to refine the technique of the experiments.

INTENSIVE EXPERIMENTS

Description of the Experiments

During the fall of 1934 and spring of 1935 four experiments were conducted at both Charleston and Baton Rouge in which improved technique was employed, permitting a more accurate comparison of the treatments. These will be referred to as experiments 1, 2, 3, and 4, the order in which they were conducted. Experiment 1 was conducted during the fall of 1934 and the other three during the spring of 1935. Cabbage of medium size, in the preheading stage, was used in experiments 1 and 2, plants starting to head in experiment 3, and those nearing maturity in experiment 4. The Copenhagen Market variety of cabbage was used in experiment 1 and the Charleston Wakefield in 2, 3, and 4. Each experiment consisted of one application of the materials on plants not previously treated.

The plants comprising experiment 1 received two additional applications of the insecticides, but, owing to complications in the insect infestation that developed after the first application, which were especially pronounced at Baton Rouge, the data obtained from these last two applications were omitted from this report. It was found that the plots that had received the most effective early treatments apparently later contained plants more attractive for oviposition than were the badly damaged plants in the plots receiving the less effective treatments, and consequently the caterpillars at the end of the 21-day intervals allowed between applications tended to be more numerous on the plants that had been better protected.

Each experiment contained 12 treatments, namely, 4 dilutions each of derris powder and pyrethrum powder; 1 each of paris green, calcium arsenate, and synthetic cryolite; and an undusted check. China clay was used as the diluent for derris, pyrethrum, and cryolite and hydrated lime for paris green. Calcium arsenate was used undiluted. The dusts were applied at the rate of approximately 20 pounds per acre with rotary-type hand dusters by passing once to the row in experiments 1 and 2 and twice to the row, at an angle on each side, in experiments 3 and 4. The materials, with their analyses and the dilutions used, are listed in table 1.

TABLE 1.—*Materials and their analyses, diluents, and dilutions used in experiments 1 to 4, inclusive, against cabbage caterpillars, Baton Rouge, La., and Charleston, S. C., season of 1934–35*

Experiment No.	Material	Analysis	Diluent	Dilutions
		Percent		
1	Derris powder	Rotenone 3.9 Total CCl_4 extractives 17.9	China clay	To contain 1.0, 0.5, 0.1, and 0.05 percent of rotenone.
2–4	do	Rotenone 4.4 Total CCl_4 extractives 19.4	do	To contain 1.0, 0.5, 0.1, and 0.05 percent of rotenone.
1	Pyrethrum powder.	Pyrethrin I .29	do	To contain 0.1, 0.05, 0.025, and 0.0125 percent of pyrethrin I.
2–4	do	Pyrethrin I .42 Pyrethrin II .61	do	To contain 0.1, 0.05, 0.025, and 0.0125, percent of pyrethrin I.
1–4	Calcium arsenate.	Moisture 1.19 Total arsenic as As_2O_3 41.12 Water-soluble arsenic as As_2O_3 .10	None	Undiluted.
1–4	Paris green	Moisture .46 Total arsenic as As_2O_3 57.50 Water-soluble arsenic as As_2O_3 .87	Hydrated lime	1–9 parts by weight.
1–4	Cryolite (synthetic).	Equivalent of Na_3AlF_6 97.7 Fluorine 53.07 Aluminum 13.92 Moisture .23	China clay	1–3 parts by weight.

The treatments were replicated six times in each experiment and were randomized in each of six parallel blocks and six cross sections, forming a semilatin square. By this arrangement it was possible to utilize the method of analysis of variance in the interpretation of the results. A typical diagram of the field lay-out of these experiments is shown in figure 5.

In experiment 1 the plots consisted of eight rows 80 feet long including two buffer rows that were not dusted, and in experiments 2, 3, and 4 they consisted of five rows 50 feet long, including one buffer row. In experiment 1 the samples were taken from the middle four rows, and in experiments 2, 3, and 4 from all four of the treated rows. The samples consisted of counts of the surviving caterpillar populations on four 25-plant subsamples from each plot,

BLOCKS (REPLICATIONS)

SECTIONS (REPLICATIONS)	A	B	C	D	E	F
I	1	7	6	12	5	2
	11	4	3	10	9	8
II	9	12	7	1	3	4
	10	5	2	11	8	6
III	6	9	1	3	12	7
	2	10	8	5	4	11
IV	4	3	11	9	6	10
	12	2	5	8	7	1
V	5	8	9	2	1	3
	7	11	4	6	10	12
VI	8	6	10	4	2	5
	3	1	12	7	11	9

FIGURE 5.—Diagram of field lay-out in experiment 1 on the control of cabbage caterpillars. The entire field consisted of 3.7 acres divided into 72 plots 80 feet long containing 8 rows 3½ feet wide. The rows are extended from left to right. In the diagram the figures represent the various experimental treatments. Charleston, S. C., and Baton Rouge, La. 1934.

the plants in each subsample being selected so as to insure that no plant was examined more than once. In experiment 1 the subsamples were taken on the second, fourth, sixth, and eighth days after the application. In experiments 2, 3, and 4 the caterpillar counts were begun on the morning of the third day after the dusts were applied, with one subsample for the experiment taken daily, or as nearly so as was physically possible, until the four were taken. The live caterpillars present were recorded by species, with those recently batched disregarded.

Diagrams of the internal arrangement of the plots employed during the fall and spring seasons are presented in figures 6 and 7.

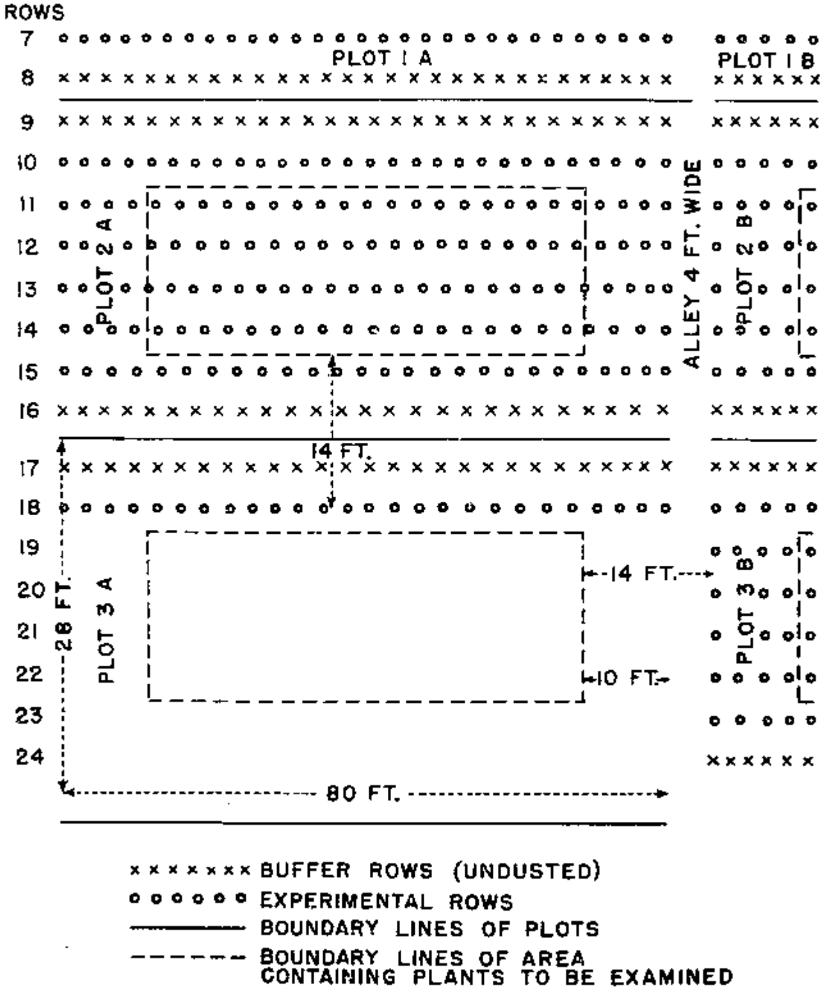

FIGURE 6.—Diagram of individual plot used in experiment 1. Plants were spaced 15 inches apart in rows 3½ feet wide. All plants in the area from which the sample was taken were at least 14 feet from plants dusted with a different material. Charleston, S. C., and Baton Rouge, La. 1934.

During the course of the experiments the following records were taken at time of application: Date, time of day, average temperature, relative humidity, relative amount of moisture on plants, sky condition, and wind velocity and direction.

From time of application to completion of sampling the dates; period from application to each count of larvae; rainfall average; minimum, maximum, and mean temperatures; and minimum, maximum, and average mean humidities were likewise recorded.

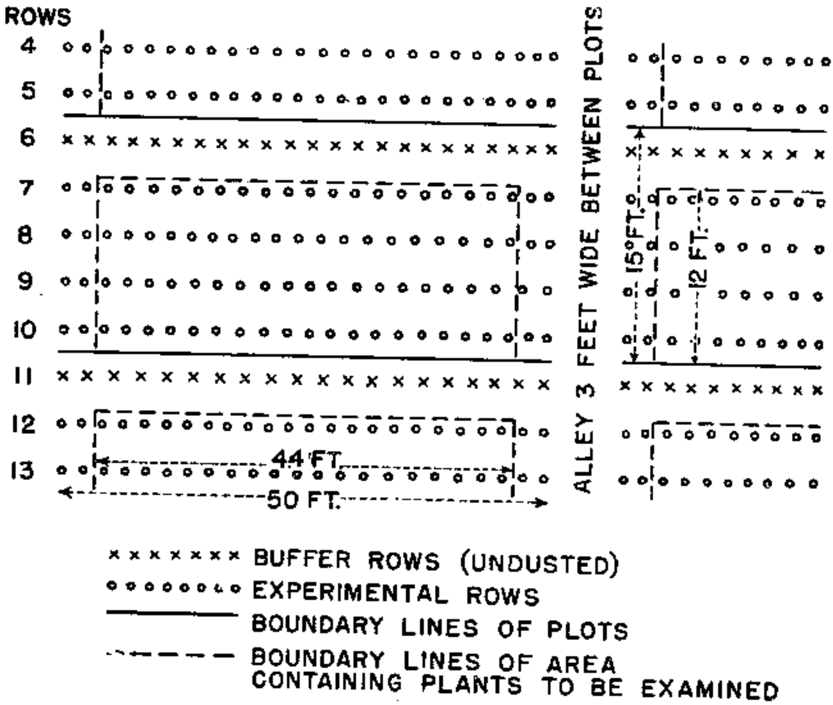

FIGURE 7.—Diagram of individual plot used in experiments 2, 3, and 4. Plants were spaced 15 inches apart in rows 3 feet wide. All plants of the area from which the sample was taken were at least 6 feet from any plant dusted with a different material. Charleston, S. C., and Baton Rouge, La. 1935.

COLLECTION AND TREATMENT OF DATA

The data on surviving caterpillars of the different species were kept separate and never averaged, because in the preliminary experiments it had been found that the species did not react the same toward the different insecticides. The data for the different experiments were first studied separately because they usually represented different levels of population. Thus a separate set of data was compiled for each species of caterpillar, for each experiment, and for each station, as illustrated in table 2, which shows the method of summarizing the counts of living cabbage loopers after the dusting with the various insecticides.

By the method of analysis of variance, the total gross variation of the experimental units in each experiment was divided into its component parts. This enabled a comparison to be made of the variation introduced by controlled factors, such as insecticidal treatment and location by blocks and sections, with that due to uncontrolled factors designated as experimental error. A test was made for each set of data in order to determine whether the estimate of variance attributed to treatment was significantly greater than that attributed to experimental error. If the value of F thus obtained was larger than the tabular value of F for a 5-percent probability, it was assumed that the means for the various treatments differed significantly among themselves. When this difference was demonstrated, the difference required between treatment means for significance was calculated from the estimated standard error. All interpretations of the results obtained in this series of experiments are based on whether or not significant differences were obtained between the treatments compared.

TABLE 2.—*Form of summary table used for recording counts of cabbage loopers in a cabbage-insecticide experiment, 1935*

Insecticide	Dilution	Rate of application per acre	Living loopers found in block—						Total	Mean per 100 plants
			A	B	C	D	E	F		
		Pounds	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Paris green-lime	1-9	21.6	60	68	58	32	77	56	351	58
Calcium arsenate	0	12.1	103	78	80	73	74	86	494	82
Cryolite-clay	1-3	21.6	74	67	28	41	43	36	289	48
Pyrethrum-clay	[1] 0.1	20.7	162	107	71	115	62	106	623	104
Do	[1] .05	22.5	125	135	80	67	124	112	643	107
Do	[1] .025	23.3	112	116	94	74	95	55	546	91
Do	[1] .0125	19.9	124	131	115	87	124	73	654	109
Derris-clay	[2] 1.0	22.0	67	36	53	31	51	21	259	43
Do	[2] .5	17.7	87	78	63	97	63	73	461	77
Do	[2] .1	19.9	83	104	59	55	75	75	451	75
Do	[2] .05	17.7	114	80	105	98	71	67	544	91
Undusted			127	126	152	104	127	77	713	119
Total for blocks			1,238	1,135	958	874	986	837	6,028	
Total for sections			I, 1,092	II, 982	III, 1,073	IV, 1,078	V, 906	VI, 897	6,028	

[1] Percentage of pyrethrin I.
[2] Percentage of rotenone.

Table 3 presents the form of work sheet used in analyzing the data of individual experiments by species and by localities.

TABLE 3.—*Sample of a work sheet used in recording analysis of variance*

[Experiment 4]

Species: Cabbage looper.
Treatments: 12.
Counts: All.
Worms per 100 undusted plants=119.
Total worms=6,028.

Location: Louisiana, 1935

Correction term=504,677.5556.

TABLE OF VARIANCE

Due to—	Crude sum of squares	Corrected sum of squares	Degrees of freedom	Variance
Total	572,068.0000	67,410.4444	71	
Treatment	544,246.0000	39,568.4444	11	3,597.1313
Blocks	514,606.1667	9,928.6111	5	1,985.7222
Sections	507,970.5000	3,292.9444	5	658.5889
Remainder		14,620.4445	50	292.4089

F=3,597.1313÷292.4089=12.3.
Variance of difference between treatment means, 2(292.4089)÷6=97.4696.
Standard error of difference between treatment means,=9.873.
Required minimum significant difference, (2.008) (9.873)=19.8 worms.
Required highly significant difference, (2.678) (9.873)=26.4 worms.

After completion of the analysis the treatments were arranged in the order of effectiveness and their differences compared with the figure required for significance as illustrated in table 4.

TABLE 4.—*Summary of infestation counts of the cabbage looper for Louisiana experiment 4 (table 3)*

Material	Dilution	Rate of application	Mean number of larvae surviving on 100 plants
	Percent	*Pounds*	
Derris-clay	1	22	43
Cryolite-clay	[1] 1–3	22	48
Paris green-lime	[1] 1–9	22	58
Derris-clay	.1	20	75
Do	.5	18	77
Calcium arsenate	0	12	82
Derris-clay	.05	18	91
Pyrethrum-clay	.025	23	91
Do	.1	21	104
Do	.05	22	107
Do	.0125	20	109
Undusted			119

[1] Parts by weight. Difference required for odds of 19 to 1—19.8; difference required for odds of 99 to 1—26.4

After these data were analyzed and assembled by experiments and species in these tables, it seemed desirable to combine or average all the data obtained on each treatment for each species, irrespective of experiments and localities, so as to facilitate the interpretation by providing an estimate of the performance of each treatment under average conditions. This was accomplished by totaling the caterpillar counts from all plots for each treatment by species and dividing by the total number of plots to obtain the weighted mean. Likewise the weighted-error variance for each species was obtained by pooling the sums of squares and dividing by the total number of degrees of freedom. The corresponding standard errors and significant differences were obtained in the usual manner, as has been illustrated in table 3.

In a similar manner the data for each species were grouped by low and high levels of population. For this purpose an arbitrary division was made and those populations below 50 caterpillars per 100 undusted plants were designated as low, and those with 50 caterpillars or more per 100 plants as high. In general, the levels of population had little effect on the relative standing of the different treatments except that significant differences were more difficult to obtain under conditions of light infestation.

The data for each species were also grouped by localities, to facilitate a study of the influence, if any, of the locality on the relative effectiveness of the different treatments. This study demonstrated that the differences between the localities caused no outstanding differences between the performances of the different materials. The chief variations in this respect were traceable to the various degrees of natural infestation.

RESULTS OBTAINED

It was apparent that the most practical comparisons of the various insecticides could be made by combining the data of all the experiments. These combinations are given in tables 5 to 8 inclusive. In these tables the mean numbers of caterpillars surviving in the different treatments, as well as the mean differences between the treatments, are given and the significances of these differences are indicated.

TABLE 5.—*Cabbage loopers surviving in the 7 experiments in which the infestation was 1 or more caterpillers per 100 plants, Charleston, S. C., and Baton Rouge, La., season of 1934–35*

Treatment No.	Insecticide dust	Mean number of loopers surviving on 42 replications of 100 plants each	Differences[1] in survival between indicated treatments											
			1	2	3	4	5	6	7	8	9	10	11	12
		Number		*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1	Derris-clay (1 percent of rotenone)	29		**13**	**20**	**36**	**40**	**42**	**46**	**46**	**50**	**52**	**73**	**79**
2	Derris-clay (0.5 percent of rotenone)	42			7	**23**	**27**	**29**	**33**	**33**	**37**	**39**	**60**	**66**
3	Cryolite-clay (1–3)	49				**16**	**20**	**22**	**26**	**26**	**30**	**32**	**53**	**59**
4	Pyrethrum-clay (0.1 percent of pyrethin I)	65					4	6	10	10	**14**	**16**	**37**	**43**
5	Pyrethrum-clay (0.05 percent of pyrethrin I)	69						2	6	6	10	**12**	**33**	**39**
6	Paris green-lime (1–9)	71							4	4	8	10	**31**	**37**
7	Derris-clay (0.1 percent of rotenone)	75								0	4	6	**27**	**33**
8	Derris-clay (0.05 percent of rotenone)	75									4	6	**27**	**33**
9	Pyrethrum-clay (0.025 percent of pyrethrin I)	79										2	**23**	**29**
10	Calcium arsenate (undiluted)	81											**21**	**27**
11	Pyrethrum-clay (0.0125 percent of pyrethrin I)	102												6
12	Undusted (check)	108												

[1] A difference of 11.5 is required for minimum significance and of 15.1 for high significance. Significant differences are indicated in bold-faced type.

TABLE 6.—*Larvae of the diamondback moth surviving in the 7 experiments in which the infestation was 1 or more caterpillars per 100 plants, Charleston, S. C., and Baton Rouge, La., season of 1934–35*

Treatment No.	Insecticide dust	Mean number of caterpillars surviving on 42 replications of 100 plants each	Differences[1] in survival between indicated treatments											
			1	2	3	4	5	6	7	8	9	10	11	12
		Number		*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1	Calcium arsenate (undiluted)	20		0	8	**14**	**20**	**21**	**28**	**29**	**32**	**34**	**37**	**40**
2	Derris-clay (1 percent of rotenone)	20			8	**14**	**20**	**21**	**28**	**29**	**32**	**34**	**37**	**40**
3	Derris-clay (0.5 percent of rotenone)	28				6	**12**	**13**	**20**	**21**	**24**	**26**	**29**	**32**
4	Paris green-lime (1-9)	34					6	7	**14**	**15**	**18**	**20**	**23**	**26**
5	Cryolite-clay (1-3)	40						1	**8**	**9**	**12**	**14**	**17**	**20**
6	Derris-clay (0.1 percent of rotenone)	41							7	**8**	**11**	**13**	**16**	**19**
7	Derris-clay (0.05 percent of rotenone)	48								1	4	6	**9**	**12**
8	Pyrethrum-clay (0.1 percent of pyrethrin I)	49									3	5	**8**	**11**
9	Pyrethrum-clay (0.05 percent of pyrethrin I)	52										2	5	**8**
10	Undusted (check)	54											3	6
11	Pyrethrum-clay (0.0125 percent of pyrethrin I)	57												3
12	Pyrethrum-clay (0.025 percent of pyrethrin I)	60												

[1] A difference of 7.7 is required for minimum significance and of 10.1 for high significance. Significant differences are indicated in bold-face type.

TABLE 7.—*Imported cabbageworms surviving in the 6 experiments in which the infestation was 1 or more caterpillars per 100 plants, Charleston, S. C., and Baton Rouge, La., season of 1934–35*

Treatment No.	Insecticide dust	Mean number of caterpillars surviving on 36 replications of 100 plants each	Differences[1] in survival between indicated treatments											
			1	2	3	4	5	6	7	8	9	10	11	12
		Number		*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1	Derris-clay (1 percent of rotenone)	3.0		1.6	**3.1**	**5.7**	**7.1**	**7.7**	**8.0**	**9.0**	**10.1**	**12.3**	**12.9**	**18.2**
2	Derris-clay (0.5 percent of rotenone)	4.6			1.5	**4.1**	**5.5**	**6.1**	**6.4**	**7.4**	**8.5**	**10.7**	**11.3**	**16.6**
3	Paris green-lime (1–9)	6.1				2.6	**4.0**	**4.6**	**4.9**	**5.9**	**7.0**	**9.2**	**9.8**	**15.1**
4	Derris-clay (0.1 percent of rotenone)	8.7					1.4	2.0	2.3	**3.3**	**4.4**	**6.6**	**7.2**	**12.5**
5	Calcium arsenate (undiluted)	10.1						.6	.9	1.9	**3.0**	**5.2**	**5.8**	**11.1**
6	Derris-clay (0.05 percent of rotenone)	10.7							.3	1.3	2.4	**4.6**	**5.2**	**10.5**
7	Pyrethrum-clay (0.05 percent of pyrethrin I)	11.0								1.0	2.1	**4.3**	**4.9**	**10.2**
8	Pyrethrum-clay (0.1 percent of pyrethrin I)	12.0									1.1	**3.3**	**3.9**	**9.2**
9	Pyrethrum-clay (0.025 percent of pyrethrin I)	13.1										2.2	**2.8**	**8.1**
10	Cryolite-clay (1–3)	15.3											.6	**5.9**
11	Pyrethrum-clay (0.0125 percent of pyrethrin I)	15.9												**5.3**
12	Undusted (check)	21.2												

[1] A difference of 2.7 is required for minimum significance and of 3.5 for high significance. Significant differences are indicated in bold-faced type.

TABLE 8.—*Larvae of Agrotinae surviving in the 2 experiments in which the infestation was 1 or more caterpillars per 100 plants, Charleston, S. C., and Baton Rouge, La., season of 1934–35*

Treatment No.	Insecticide dust	Mean number of caterpillars surviving on 12 replications of 100 plants each	Differences [1] in survival between indicated treatments											
			1	2	3	4	5	6	7	8	9	10	11	12
		Number		*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1	Calcium arsenate (undiluted)	4	-----	0	3	**11**	**12**	**12**	**13**	**13**	**15**	**15**	**17**	**19**
2	Paris green-lime (1–9)	4	-----	-----	3	**11**	**12**	**12**	**13**	**13**	**15**	**15**	**17**	**19**
3	Cryolite-clay (1–3)	7	-----	-----	-----	**8**	**9**	**9**	**10**	**10**	**12**	**12**	**14**	**16**
4	Pyrethrum-clay (0.05 percent of pyrethrin I)	15	-----	-----	-----	-----	1	1	2	2	4	4	**6**	**8**
5	Derris-clay (0.5 percent of rotenone)	16	-----	-----	-----	-----	-----	0	1	1	3	3	5	**7**
6	Derris-clay (1 percent of rotenone)	16	-----	-----	-----	-----	-----	-----	1	1	3	3	5	**7**
7	Pyrethrum-clay (0.0125 percent of pyrethrin I)	17	-----	-----	-----	-----	-----	-----	-----	0	2	2	4	**6**
8	Pyrethrum-clay (0.1 percent of pyrethrin I)	17	-----	-----	-----	-----	-----	-----	-----	-----	2	2	4	**6**
9	Pyrethrum-clay (0.025 percent of pyrethrin I)	19	-----	-----	-----	-----	-----	-----	-----	-----	-----	0	2	4
10	Derris-clay (0.1 percent of rotenone)	19	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	2	4
11	Derris-clay (0.05 percent of rotenone)	21	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	2
12	Undusted (check)	23	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

[1] A difference of 5.2 is required for minimum significance and 6.9 for high significance. Significant differences are indicated in bold-faced type.

Discussion of the Results

In the 8 experiments there were 48 plots for each treatment and 4,800 plants were examined. There were 7,808 cabbage caterpillars found on the undusted plants. Of these approximately 58 percent were cabbage loopers, 29 percent were larvae of the diamondback moth, 10 percent were imported cabbageworms, and 3 percent were Agrotinae.

The intensive experiments of the 1934–35 season resulted in a greater number of significant comparisons of the various materials than were obtained during the preliminary tests. There were some variations in the behavior of some of the materials under different conditions and against different species of caterpillars.

In studying and interpreting the results obtained in these experiments, materials are not considered different in their effect unless the differences meet the standard set up for significance. When one material is referred to as better than another it can be assumed that the difference is significant. The term "effective" implies that the use of the material resulted in a survival of caterpillars significantly lower than that in the undusted plots.

It will be noted in tables 5–8 that all materials were effective in the case of loopers and imported cabbageworms except the most dilute pyrethrum (containing 0.0125 percent of pyrethrin I), which was not effective as far as loopers were concerned. When used against larvae of the diamondback moth, however, and particularly when used against the Agrotinae, some materials were not effective. The pyrethrum dilutions and the most dilute derris (0.05 percent of rotenone) were not effective in the case of larvae of the diamondback moth, and derris containing 0.1 and 0.05 percent of rotenone together with pyrethrum containing 0.025 percent of pyrethrin I were not effective in the case of the Agrotinae.

The effectiveness of derris (1 and 0.5 percent of rotenone) when used against loopers, larvae of the diamondback moth, and imported cabbageworms is outstanding, as is the performance of the inorganic materials in the case of the Agrotinae. It is of interest to note the position of cryolite when used for loopers as compared with its rating against the imported cabbageworms. The performances of calcium arsenate against larvae of the diamondback moth and that of paris green against imported cabbageworms are worthy of notice. The materials compared fall into the following three natural groups: Derris dilutions, pyrethrum dilutions, and the inorganic insecticides. These groups were studied independently (table 9).

TABLE 9.—*Differences demonstrated between certain insecticides for statistical odds of at least 19 to 1 in favor of one over another*

CABBAGE LOOPER

Experiment No. and State	Larvae per 100 undusted plants	1-percent rotenone is better than—			0.5-percent rotenone is better than—		0.1-percent rotenone is better than—	0.1-percent pyrethrin I is better than—			0.05-percent pyrethrin I is better than—		0.025-percent pyrethrin I is better than—	Calcium arsenate is better than—		Paris green is better than—		Cryolite is better than—	
		0.5	0.1	0.05	0.1	0.05	0.05	0.05	0.025	0.0125	0.025	0.0125	0.0125	Paris green	Cryolite	Calcium arsenate	Cryolite	Calcium arsenate	Paris green
	Number																		
1, Louisiana	500	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	No	No	No	No	Yes	Yes
1, South Carolina	28	No	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	No	No	No	No	No	No	No
2, Louisiana	8	No	No	No	No	No	No	Yes	Yes	Yes	No	Yes	No	No	No	No	No	No	No
2, South Carolina	(1)																		
3, Louisiana	22	No	No	Yes	No	No	No	No	No	Yes	No	No	Yes	No	No	No	No	No	No
3, South Carolina	26	No	No	Yes	No	Yes	No	No	No	Yes	No	No	No	No	No	No	No	No	No
4, Louisiana	119	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	Yes	No	Yes	No
4, South Carolina	41	No	No	Yes	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No
Low [2]	25	No	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	No	No	No	No	No	No	No
High [3]	314	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	No	No	No	No	Yes	Yes
All Louisiana	165	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	No	No	No	No	Yes	Yes
All South Carolina	32	No	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	No	No	No	No	No	No	No
All experiments	108	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	No	No	No	No	Yes	Yes

DIAMONDBACK MOTH LARVAE

Experiment No. and State	Larvae per 100 undusted plants	1-percent rotenone: 0.5	0.1	0.05	0.5-percent rotenone: 0.1	0.05	0.1-percent rotenone: 0.05	0.1-percent pyrethrin I: 0.05	0.025	0.0125	0.05-percent pyrethrin I: 0.025	0.0125	0.025-percent pyrethrin I: 0.0125	Calcium arsenate: Paris green	Cryolite	Paris green: Calcium arsenate	Cryolite	Cryolite: Calcium arsenate	Paris green
1, Louisiana	9	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	No	Yes	No	No	No	No	No
1, South Carolina	(1)																		
2, Louisiana	12	No	Yes	No	Yes	No	No	No	No	No	No	No	No	Yes	Yes	No	No	No	No
2, South Carolina	15	No	Yes	Yes	No	Yes	No	No	No	No	Yes	No	No	No	Yes	No	No	No	No
3, Louisiana	17	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes	No	No	No	No
3, South Carolina	78	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	Yes	No	No	No	No
4, Louisiana	130	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	Yes	No	No	No	No
4, South Carolina	113	No	Yes	Yes	Yes	Yes	No	No	Yes	No	No	No	No	Yes	Yes	No	No	No	No
Low [2]	13	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No
High [3]	107	No	Yes	Yes	Yes	Yes	No	No	Yes	No	No	No	No	Yes	Yes	No	No	No	No
All Louisiana	42	Yes	Yes	Yes	No	Yes	No	No	No	No	No	Yes	No	Yes	Yes	No	No	No	No
All South Carolina	69	No	Yes	Yes	Yes	Yes	No	No	Yes	No	No	No	No	Yes	Yes	No	No	No	No
All experiments	54	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No	No	No	No

See footnotes at end of table.

TABLE 9.—*Differences demonstrated between certain insecticides for statistical odds of at least 19 to 1 in favor of one over another*—Continued

IMPORTED CABBAGEWORM

Experiment No. and State	Larvae per 100 undusted plants	1-percent rotenone is better than—			0.5-percent rotenone is better than—		0.1-percent rotenone is better than—	0.1-percent pyrethrin I is better than—			0.05-percent pyrethrin I is better than—		0.025-percent pyrethrin I is better than—	Calcium arsenate is better than—		Paris green is better than—		Cryolite is better than—	
		0.5	0.1	0.05	0.1	0.05	0.05	0.05	0.025	0.0125	0.025	0.0125	0.0125	Paris green	Cryolite	Calcium arsenate	Cryolite	Calcium arsenate	Paris green
	Number																		
1, Louisiana	(1)	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------
1, South Carolina	0	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------
2, Louisiana	22	No	Yes	Yes	No	No	No	No	No	No	No	Yes	No	No	No	Yes	Yes	No	No.
2, South Carolina	5	No	No	Yes	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No.
3, Louisiana	24	No	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No	No.
3, South Carolina	2	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No.
4, Louisiana	54	No	Yes	Yes	No	Yes	No	No	No	No	No	No	No	No	No	No	Yes	No	No.
4, South Carolina	21	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	No	No.
Low [2]	15	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No.
High [3]	54	No	Yes	Yes	No	Yes	No	No	No	No	No	No	No	No	No	No	Yes	No	No.
All Louisiana	33	No	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	No	No	Yes	Yes	Yes	No	No.
All South Carolina	9	No	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	No	No.
All experiments	21	No	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No	No.

[1] Trace.
[2] Those experiments with infestations below 50 larvae per 100 plants.
[3] Those experiments with infestations of 50 or more larvae per 100 plants.

DERRIS DILUTIONS

According to the data presented in table 9, comparisons of the four dilutions of derris as used against the three species of green cabbage caterpillars[9] indicate that the reductions obtained were correlated with the strengths of the dilutions employed.

For the cabbage loopers the 1-percent dilution was superior to the 0.5-percent dilution in one experiment only; however, when the experiments were grouped for high-level larval populations, by all Louisiana experiments, and by all experiments of both localities, it was superior. No significant differences between the 1-percent and the 0.5-percent dilutions were demonstrated in the experiments grouped by low-level populations or in the grouping of all South Carolina experiments, all of which had low-level populations.

For the larvae of the diamondback moth the same was true except that no significant difference was demonstrated in the case of the group with high-level populations.

For the imported cabbageworm the 1-percent dilution was not superior to the 0.5-percent dilution, but in practically all instances both were superior to the 0.1- and 0.05-percent dilutions. Few differences between the two most dilute dusts were demonstrated, both of which are doubtless too weak for any practical purpose.

From these data it can be concluded that for cabbage caterpillar populations, consisting largely of the cabbage looper and diamondback moth, a derris dilution containing 1 percent of rotenone should be most effective, while a 0.5-percent dilution should be sufficient where the imported cabbageworm is the more numerous.

PYRETHRUM DILUTIONS

As indicated in table 9 the reaction of the cabbage caterpillars to pyrethrum powder was somewhat erratic. There were marked variations in its effectiveness against the different species, against groups of the same species, and in the action of the various dilutions of the material.

No significant differences were demonstrated between the two greater strengths of pyrethrum (containing 0.1 and 0.05 percent of pyrethrin I) against any of the three species of green caterpillars, in all experiments combined, or in any grouping of the various experiments. The 0.1-percent dust proved superior to the 0.05-percent dust in two individual experiments, in both of which the populations were low, and indications were that the differences shown were more likely due to differences in population than to the effect of treatment. Comparisons of the other dilutions with each remaining lesser strength showed a definite trend for the greater strength to be superior to the next weaker dilution. This trend was not so pronounced, however as in the case of the comparisons of the different derris dilutions.

Pyrethrum showed most effectiveness against the cabbage looper and least against the larvae of the diamondback moth.

[9] The cabbage looper, the larva of the diamondback moth, and the imported cabbageworm.

INORGANIC MATERIALS

According to the comparisons given in table 9, cryolite was slightly more effective in reducing the populations of loopers than was either calcium arsenate or paris green. Although cryolite was demonstrated to be superior to paris green in only one experiment and to calcium arsenate in two experiments, in the grouping of the experiments significant differences were demonstrated for high-level populations, for all Louisiana experiments, and for all experiments combined. In a single experiment paris green was demonstrated to be superior to calcium arsenate, but no differences were demonstrated between these materials in any of the groupings of the experiments.

For the larvae of the diamondback moth significant differences favorable to calcium arsenate were demonstrated in practically all comparisons. For the imported cabbageworm the comparisons made demonstrated that paris green was most effective and cryolite least effective.

COMPARISONS OF THE FIVE MOST PROMISING TREATMENTS

The differences demonstrated between the effectiveness of the five most promising treatments are compared in tables 10 to 13, inclusive. These are on the basis of reduction with one dusting of the populations of the cabbage looper, the diamondback moth, the imported cabbageworm, and the Agrotinae. In addition, these tables contain summaries, by species, of the various combinations of the data.

TABLE 10.—*Differences demonstrated, for statistical odds of at least 19 to 1, between the effectiveness of the five most promising treatments in reducing populations of cabbage loopers*

Experiment No. and State	Larvae per 100 undusted plants	Derris (1-percent) better than—				Cryolite better than—				Derris (0.5-percent) better than—			
		Cryolite	Derris (0.5-percent)	Paris green	0.1-percent pyrethrin I	Derris (1-percent)	Derris (0.5-percent)	Paris green	0.1-percent pyrethrin I	Derris (1-percent)	Cryolite	Paris green	0.1-percent pyrethrin I
	Number												
1, Louisiana	509	Yes	No	Yes	Yes	No	No	Yes	No	No	No	Yes	Yes.
1, South Carolina	28	No	No	No	No	No	No	No	No	No	No	No	No.
2, Louisiana	8	No	No	No	No	No	No	No	No	No	No	No	No.
2, South Carolina	(1)												
3, Louisiana	22	No	No	No	No	No	No	No	No	No	No	No	No.
3, South Carolina	26	No	No	No	No	No	No	No	No	No	No	No	No.
4, Louisiana	119	No	Yes	No	Yes	No	Yes	No	Yes	No	No	No	Yes.
4, South Carolina	41	No	No	No	Yes	No	No	No	No	No	No	No	Yes.
Low [2]	25	No	No	No	Yes	No	No	No	No	No	No	No	No.
High [3]	314	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes.
All Louisiana	165	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes.
All South Carolina	32	No	No	No	No	No	No	No	No	No	No	No	No.
All experiments	108	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes.

Experiment No. and State	Larvae per 100 undusted plants	Paris green better than—				0.1-percent pyrethrin I better than—			
		Derris (1-percent)	Cryolite	Derris (0.5-percent)	0.1-percent pyrethrin I	Derris (1-percent)	Cryolite	Derris (0.5-percent)	Paris green
	Number								
1, Louisiana	509	No	No	No	No	No	No	No	Yes.
1, South Carolina	28	No	No	No	No	No	Yes	Yes	Yes.
2, Louisiana	8	No	No	No	No	No	No	No	No.
2, South Carolina	(1)								
3, Louisiana	22	No	No	Yes	Yes	No	No	No	No.
3, South Carolina	26	No	No	No	No	No	No	No	No.
4, Louisiana	119	No	No	No	Yes	No	No	No	No.
4, South Carolina	41	No	No	No	No	No	No	No	No.
Low [2]	25	No	No	No	No	No	No	No	No.
High [3]	314	No	No	No	No	No	No	No	No.
All Louisiana	165	No	No	No	No	No	No	No	No.
All South Carolina	32	No	No	No	No	No	No	No	No.
All experiments	108	No	No	No	No	No	No	No	No.

[1] Trace.
[2] Those experiments with infestations below 50 larvae per 100 plants.
[3] Those experiments with infestations of 50 or more larvae per 100 plants.

TABLE 11.—*Differences demonstrated, for statistical odds of at least 19 to 1, between the effectiveness of the five most promising materials in reducing the populations of diamondback moth larvae on cabbage*

Experiment No. and State	Larvae per 100 undusted plants	Derris (1-percent) better than—				Calcium arsenate better than—				Derris (0.5-percent) better than—			
		Calcium arsenate	Derris (0.5-percent)	Paris green	Cryolite	Derris (1-percent)	Derris (0.5-percent)	Paris green	Cryolite	Derris (1-percent)	Calcium arsenate	Paris green	Cryolite
	Number												
1, Louisiana	9	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes.
1, South Carolina	(1)												
2, Louisiana	12	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes.
2, South Carolina	15	No	No	No	Yes	No	No	No	Yes	No	No	No	No.
3, Louisiana	17	No	No	No	No	No	Yes	No	Yes	No	No	No	No.
3, South Carolina	78	No	No	No	No	No	No	No	Yes	No	No	No	No.
4, Louisiana	130	No	Yes	Yes	Yes	No	No	No	Yes	No	No	No	No.
4, South Carolina	113	No	No	No	No	No	No	Yes	Yes	No	No	No	Yes.
Low [2]	13	No	No	Yes	Yes	No	No	Yes	Yes	No	No	No	Yes.
High [3]	107	No	No	Yes	Yes	No	No	Yes	Yes	No	No	No	Yes.
All Louisiana	42	No	Yes	Yes	Yes	No	No	Yes	Yes	No	No	No	No.
All South Carolina	69	No	No	No	Yes	No	No	Yes	Yes	No	No	No	Yes.
All experiments	54	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	Yes.

Experiment No. and State	Larvae per 100 undusted plants	Paris green better than—				Cryolite better than—			
		Derris (1-percent)	Calcium arsenate	Derris (0.5 percent)	Cryolite	Derris (1-percent)	Calcium arsenate	Derris (0.5-percent)	Paris green
	Number								
1, Louisiana	9	No	No	No	No	No	No	No	No.
1, South Carolina	(1)								
2, Louisiana	12	No	No	No	No	No	No	No	No.
2, South Carolina	15	No	No	No	No	No	No	No	No.
3, Louisiana	17	No	No	No	No	No	No	No	No.
3, South Carolina	78	No	No	No	No	No	No	No	No.
4, Louisiana	130	No	No	No	No	No	No	No	No.
4, South Carolina	113	No	No	No	No	No	No	No	No.
Low [2]	13	No	No	No	No	No	No	No	No.
High [3]	107	No	No	No	No	No	No	No	No.
All Louisiana	42	No	No	No	No	No	No	No	No.
All South Carolina	69	No	No	No	No	No	No	No	No.
All experiments	54	No	No	No	No	No	No	No	No.

[1] Trace.
[2] Those experiments with infestations below 50 larvae per 100 plants.
[3] Those experiments with infestations of 50 or more larvae per 100 plants.

TABLE 12.—*Differences demonstrated, for statistical odds of at least 19 to 1, between the effectiveness of the five most promising treatments in reducing populations of the imported cabbageworm*

Experiment No. and State	Larvae per 100 undusted plants	Derris (1-percent) better than—				Derris (0.5-percent) better than—				Paris green better than—			
		Derris (0.5-percent)	Paris green	Calcium arsenate	0.1-percent pyrethrin I	Derris (1-percent)	Paris green	Calcium arsenate	0.1-percent pyrethrin I	Derris (1-percent)	Derris (0.5-percent)	Calcium arsenate	0.1-percent pyrethrin I
	Number												
1, Louisiana	(1)												
1, South Carolina	0												
2, Louisiana	22	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes.
2, South Carolina	5	No	No	No	No	No	No	No	No	No	No	No	No.
3, Louisiana	24	No	No	No	Yes	No	No	Yes	Yes	No	No	Yes	Yes.
3, South Carolina	2	No	No	No	No	No	No	Yes	No	No	No	No	No.
4, Louisiana	54	No	Yes	Yes	Yes	No	No	Yes	Yes	No	No	No	Yes.
4, South Carolina	21	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes.
All Louisiana	33	No	Yes	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes.
All South Carolina	9	No	No	No	Yes	No	No	No	Yes	No	No	No	Yes.
All experiments	21	No	Yes	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes.

Experiment No. and State	Larvae per 100 undusted plants	Calcium arsenate better than—				0.1-percent pyrethrin I better than—			
		Derris (1-percent)	Derris (0.5-percent)	Paris green	0.1-percent pyrethrin I	Derris (1-percent)	Derris (0.5-percent)	Paris green	Calcium arsenate
	Number								
1, Louisiana	(1)								
1, South Carolina	0								
2, Louisiana	22	No	No	No	No	No	No	No	No.
2, South Carolina	5	No	No	No	No	No	No	No	No.
3, Louisiana	24	No	No	No	No	No	No	No	No.
3, South Carolina	2	No	No	No	No	No	No	No	No.
4, Louisiana	54	No	No	No	No	No	No	No	No.
4, South Carolina	21	No	No	No	Yes	No	No	No	No.
All Louisiana	33	No	No	No	No	No	No	No	No.
All South Carolina	9	No	No	No	No	No	No	No	No.
All experiments	21	No	No	No	No	No	No	No	No.

[1] Trace.

TABLE 13.—*Differences demonstrated, for statistical odds of at least 19 to 1, between the effectiveness of the five most promising treatments in reducing the populations of larvae of the Agrotinae*

Experiment No. and State	Larvae per 100 undusted plants	Calcium arsenate better than—				Paris green better than—				Cryolite better than—			
		Paris green	Cryolite	Pyrethrum	Derris	Calcium arsenate	Cryolite	Pyrethrum	Derris	Calcium arsenate	Paris green	Pyrethrum	Derris
	Number												
1, Louisiana	7	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	No.
1, South Carolina	38	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes.
Both	23	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes.

Experiment No. and State	Larvae per 100 undusted plants	0.1-percent pyrethrin I better than—				Derris (1-percent) better than—			
		Calcium arsenate	Paris green	Cryolite	Derris	Calcium arsenate	Paris green	Cryolite	Pyrethrum
	Number								
1, Louisiana	7	No	No	No	No	No	No	No	No.
1, South Carolina	38	No	No	No	No	No	No	No	No.
Both	23	No	No	No	No	No	No	No	No.

In table 10 it is of interest to note that in the grouping of all the experiments three of the five materials show decided superiority against the cabbage looper. Paris green and pyrethrum (containing 0.1 percent of pyrethrin I) were generally inferior to the derris dilutions and cryolite. The various combinations of experiments had a tendency to emphasize the superiority of the least dilute derris dust. Certain conflicts in the results of individual experiments will be noted. The greatest conflict is found in the comparisons of the pyrethrum dilution and paris green. No reasonable explanation was found for this inconsistency, except that pyrethrum was apparently more effective against populations of small larvae than against those consisting chiefly of large larvae. It does not appear to be a question of locality or level of population, as this conflict is not apparent in the combinations.

Table 11 gives evidence of the effectiveness of calcium arsenate in the case of larvae of the diamondback moth. Both calcium arsenate and derris (1.0 percent of rotenone) were of outstanding effectiveness. No conflicts are noticeable in the individual experiments.

In the case of the imported cabbageworm the evidence as shown in table 12 is decidedly in favor of the derris dilutions and paris green, with little to choose between the two derris dilutions. No conflicts are apparent in this table. Population levels were too low for the usual combinations to be made.

The superiority of the inorganic materials when used against the Agrotinae is clearly shown in table 13. There does not appear to be any difference between the effectiveness of paris green, calcium arsenate, and cryolite.

A comparison of tables 10–13 brings out the fact that the only erratic results are to be found in the data for the cabbage looper.

Variable results were obtained with the pyrethrum dusts, both as regards different species of caterpillars and populations of the same species. Several factors might have been involved to account for the relative ineffectiveness and the variability of pyrethrum throughout the experiments. It may be that clay was not a suitable diluent for pyrethrum and had a tendency to reduce its toxic value. The dusts employed were probably more diluted than they should be for use in agricultural practices. The effectiveness of pyrethrum is dependent on contact with the insects, and the limitations imposed by field applications and variations in weather and plant conditions are no doubt greater than for any of the other materials.

The effectiveness of derris is apparent by virtue of the fact that it stands out prominently in all comparisons except those for the Agrotinae.

Paris green appears in all comparisons but does not show to any advantage except in the case of the Agrotinae and the imported cabbageworm.

Cryolite was of considerable value when used against the cabbage looper and the Agrotinae, but was relatively inferior in other cases.

SUMMARY AND CONCLUSIONS

The risk of using arsenicals in combating caterpillars on cabbage during the latter part of head development and the paramount need for the protection of the crop during this period made necessary an intensive study of cabbage-caterpillar insecticides. Consequently a study was initiated in which were utilized some of the available organic substitutes considered to be less poisonous to man, together with several inorganic insecticides.

This bulletin reports the results of experiments conducted at Charleston, S. C., and Baton Rouge, La., from the winter of 1932–1933 through the spring of 1935. The experiments are divided into two natural groups with those of a preliminary nature in one and those of an intensive nature in the other.

The cultural practices employed were those of the respective localities. The caterpillars found consisted largely of the cabbage looper (*Autographa brassicae*), the diamondbackmoth (*Plutella maculipennis*), the imported cabbageworm (*Pieris rapae*), and several species of the Agrotinae consisting mostly of the corn earworm (*Heliothis armigera*), and two species of true cutworms.

The materials tested consisted of various dilutions of derris-root powder, pyrethrum flowers (powdered), synthetic and natural cryolites, barium fluosilicate, hellebore, paris green, and calcium arsenate. Talc, china clay, sulfur, tobacco dust, and lime were used as diluents for one or more of the insecticidal materials.

In all the experiments, use was made of replicated plots and in most cases some degree of randomization. As the studies progressed the technique of experimental design was improved, permitting for the intensive studies a statistical treatment of the data and a better interpretation of the results.

The preliminary experiments indicated that derris and pyrethrum were comparable and sometimes superior to the arsenicals and fluorine compounds in reducing the populations of the three common species of green cabbage caterpillars (the cabbage looper, the larva of the diamondback moth, and the imported cabbageworm); that these organic materials could be used effectively at less than full strength; that the toxicity of all the materials, organic and inorganic, varied with the different species; and that hellebore was relatively ineffective against any of the cabbage caterpillars.

The intensive studies consisted of comparisons of 4 dilutions each of derris and pyrethrum powders and 1 each of cryolite and paris green, and undiluted calcium arsenate in 4 experiments at both Baton Rouge and Charleston. Each of the 11 treatments and an undusted check were replicated 6 times in each of 8 semilatin-square experiments. Results were based on the comparative number of caterpillars surviving on 100 plants receiving each treatment replication. Analyses of variance of the data of the individual experiments and of various combinations of the experiments were used in interpreting the results.

Against the cabbage looper the 1-percent-rotenone derris dust was superior to all other treatments. The 0.5-percent-rotenone derris dust and the synthetic cryolite diluted with 3 parts of china clay were next in effectiveness. These differed little in effectiveness and both were superior to the pyrethrum dusts containing 0.1 and 0.05 percent of pyrethrin I.

Against the larvae of the diamondback moth the derris dust containing the 1 percent of rotenone and the calcium arsenate, undiluted, were significantly superior to all other treatments and of approximately equal effectiveness. The derris dust containing 0.5 percent of rotenone was next in effectiveness. All other treatments were relatively ineffective against this species.

The imported cabbageworm proved to be very susceptible to derris powder. The dilutions of derris containing 1 and 0.5 percent of rotenone were most effective and not significantly different from one another. Paris green was the only other material showing any comparable degree of effectiveness, calcium arsenate, pyrethrum, and cryolite being relatively inferior.

Against the Agrotinae the three inorganic materials—calcium arsenate, paris green, and cryolite—were most effective. These insecticides gave similar results and each was superior to derris and pyrethrum. Some dilutions of derris and pyrethrum were toxic but not sufficiently so to be satisfactory insecticides for this group of caterpillars.

The derris dusts gave the most uniform performance of the materials tested. In one or more of their dilutions they were among the most effective for each species except the Agrotinae. Although not evident in the figures as utilized in the analyses of these experiments, a decided residual effect was noted in the use of derris.

The evidence obtained in these investigations indicates that a derris dust mixture containing from 0.5 to 1 percent of rotenone is sufficiently toxic to each species of cabbage caterpillars of importance in the South, with the exception of the Agrotinae, to be of value as a substitute for arsenicals in practical field control, and that pyrethrum diluted to contain 0.1 percent of pyrethrin I is of value when directed against the imported cabbageworm and the cabbage looper.

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