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EUROPEAN CORN BORER INVESTIGATIONS

Experiments with Insecticides on Early Sweet Corn

C. H. Batchelder, D. D. Questel
and Neely Turner

United States Department of Agriculture, Washington, D. C.
In Coöperation with the Connecticut Agricultural Experiment Station.

Connecticut
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C. H. Batchelder[1], D. D. Questel and Neely Turner

THIS INVESTIGATION was undertaken for the purpose of determining the effectiveness of preparations of fixed nicotine, rotenone, and phenothiazine when employed against the first generation of the European corn borer (*Pyrausta nubilalis* Hubn.), under conditions prevailing in the State of Connecticut. The experiments were conducted in the New Haven laboratories and on the Mount Carmel farm of the Connecticut Agricultural Experiment Station, and in commercial fields of early market sweet corn at Glastonbury and Hamden, Connecticut.

Prior to the establishment of these coöperative studies, C. H. Batchelder and D. D. Questel, of the Bureau of Entomology and Plant Quarantine, had tentatively established the following facts in preliminary experiments: (a) That certain forms of fixed nicotine applied in sprays were toxic to larvæ of the European corn borer; (b) that these materials were more effective when used with a suitable spreader; (c) that sprays applied to the growing whorls of leaves during the period in which eggs of the European corn borer were hatching would reduce infestation by the corn borer; and (d) that the materials applied in this way gave a substantial amount of protection from crop injury by the European corn borer to early market sweet corn in commercial fields.

The specific objectives of the experiments described in this report were: (a) to investigate forms of fixed nicotine other than nicotine tannate; (b) to determine the insecticidal effectiveness of derris and phenothiazine; and (c) to ascertain whether or not these insecticidal agents could be satisfactorily employed with a dust carrier.

MATERIALS

The various forms in which nicotine, rotenone, and phenothiazine were employed in field-plot experiments are described in the paragraphs to follow. Concentrations of the active agents and of the spreaders are included in Tables 2, 3, and 4, which list the insecticides used and the results obtained with them. All quantities mentioned are by weight, unless otherwise specified.

Insecticidal Preparations

The standard nicotine tannate spray was prepared in barrels immediately before use by reacting dilute solutions of nicotine and Chinese gallotannin during agitation. The proportions used were 1 part free nicotine (50 percent) and 3 parts liquid tannin (Chinese gallotannin) in 800 parts water.

[1]C. H. Batchelder, Associate Entomologist, and D. D. Questel, Junior Entomologist, Division of Cereal and Forage Insect Investigations, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

Neely Turner, Assistant Entomologist, Department of Entomology of this Station.

Dual-fixed nicotine was prepared by mixing 25 parts of nicotine tannate powder (20 percent nicotine) with 75 parts of powdered nicotine bentonite (9.34 percent nicotine) made by drying and grinding a preparation of nicotine sulfate and bentonite. The mixture contained approximately 12 percent nicotine. A spray preparation of this dry, powdered material was made by weighing out the required amount, adding to it enough water to produce a thin paste, and stirring the paste into the spray water. It was then applied as a suspension. Dual-fixed nicotine was also applied in dust form with a talc carrier. At the time of mixing these materials, dry butyl phenyl-phenol sodium sulfonate was added for the purpose of improving the adhesiveness of the product. A rotating barrel mixer was employed to prepare the dust, which was then stored in airtight containers until used in the field. Similar methods were employed in assembling other dry, powdered insecticides for use either as sprays or as dusts. Dual-fixed nicotine was used in spray, 4 pounds to 100 gallons of water. In dust form, with an equal weight of talc, it contained 6 percent nicotine.

The preparation of nicotine tannate powder used in these experiments consisted of nicotine tannate dried on kaolin and ground to pass a 200-mesh sieve. It had a nicotine content of 4 percent. Except in nicotine content, this tannate was identical with that used in the preparation of dual-fixed nicotine as previously described. Nicotine tannate powder was used in spray, 10 pounds to 100 gallons of water. In dust form it was used without dilution.

Nicotine tannate in alcohol consisted of 25 parts of free nicotine (50 percent) with 75 parts of liquid gallotannin in 400 parts methanol. It was believed that a mixture assembled in this manner might result in a stable combination of the nicotine and the tannin when diluted in the spray water. It was designed with the object of providing the user with a simpler method of preparing a fixed nicotine spray. This stock solution was used in spray, 1 part to 40 parts (by weight) of water.

Nicotine bentonite with zinc oleate adhesive was composed of 63 percent of nicotine bentonite (dried and ground to a powder), 12 percent of sodium oleate, 6 percent of nicotine-zinc chloride, and 19 percent of bentonite. The mixture contained 8 percent nicotine. It was used with the thought that the formation of zinc oleate in the spray would increase the adhesiveness of the spray residue. This was considered necessary because dry powdered nicotine bentonite is subject to loss through washing during rains. Six pounds of the mixture were used in 100 gallons of water.

Nicotine bentonite with petroleum oil adhesive was composed of 88.35 percent nicotine bentonite (dried and ground to a powder), 4.65 percent heavy petroleum oil, and 7 percent butyl phenyl-phenol sodium sulfonate. It contained 13 percent nicotine and was used in sprays at the rate of 4 pounds per 100 gallons of water; in dusts, 1 part was mixed with 3 parts of talc.

Tank-mixed nicotine bentonite was prepared by mixing 1 pint of nicotine sulfate (40 percent) with 4 pounds of bentonite in 100 gallons of water.

The ground derris consisted of crude derris root ground to a powder that passed a 200-mesh sieve; the rotenone content of the product used in 1935 was 3.9 percent and of that used in 1936, 4 percent; the content of total carbon tetrachloride extractive of the product used in 1935 was 16.1 percent and of the product used in 1936, 14 percent. The derris was used in spray, 4 pounds to 100 gallons of water; in dust form, 1 part to 8 parts of talc were used to obtain approximately 0.4 percent rotenone content.

The ground cubé used in the 1936 experiments consisted of crude cubé root ground to a powder that passed a 200-mesh sieve; the rotenone content was 4 percent. It was applied with talc as a dust containing 0.8 percent rotenone.

An acetone extract of derris which contained 5 grams of rotenone in 100 cubic centimeters was used. This stock solution was used in spray at the rate of one part in 250 parts (by volume) of water.

The re-crystallized phenothiazine used in 1935 contained 2 percent sodium lauryl sulfate and was ground to pass a 200-mesh sieve. It was used in spray, 4 pounds to 100 gallons of water; in dust form, 1 part to 32 parts of talc. In 1936 a technical grade of phenothiazine in excess of 99 percent

Figure 34. Method of applying sprays to the whorl of primary stalks. Tiller growth was treated in a similar manner.

purity was used. This material contained 0.5 percent sodium lauryl sulfate and was ground to pass a 200-mesh sieve. Sodium lauryl sulfate had been added only for the purpose of making dry phenothiazine wettable when preparing a spray. Its dilution was so great as to render negligible its presence in sprays.

Spreading Agents Employed

Spreading agents were necessary in these insecticides to carry them farther into the interfoliar and other spaces of the developing plant where early-instar larvæ of the borer are sheltered. Preliminary laboratory and greenhouse studies (1935 and 1936) showed that preparations of ammonium sulfo soap and butyl phenyl-phenol sodium sulfonate were useful for this purpose without causing injury to the plants. These materials were used as spreading agents in preparing certain sprays for field-plot tests. They were dissolved in the spray water before adding the insecticide.

The *ammonium sulfo soap* was a crude product consisting of sulfo acids neutralized with ammonia. It was derived from the manufacture of purified petroleum and had a water content of 40 percent. Its performance as a spreading agent was satisfactory when employed with insecticides, except phenothiazine, the particles of which appeared to agglomerate in ammonium sulfo soap solutions.

Butyl phenyl-phenol sodium sulfonate in dry, powder form was also extensively used as a spreading agent in these experiments. It was not so satisfactory as ammonium sulfo soap when employed as a dispersing and spreading agent for the derris extract. It was added to all insecticidal dusts for the purpose of increasing their adhesiveness.

METHODS OF PROCEDURE

The field experiments reported here were conducted in early plantings of the common commercial sweet corn variety, Golden Early Market. Treatments were applied to plots composed of 60 hills in 4 rows. These were replicated 4 or 6 times in randomized Latin-square arrangement. Test materials were applied by means of hand-operated dusters and sprayers. Extension tubes were employed in directing sprays or dusts at the whorls, emerging tassels, and developing ears of the plants treated. (Figure 34.)

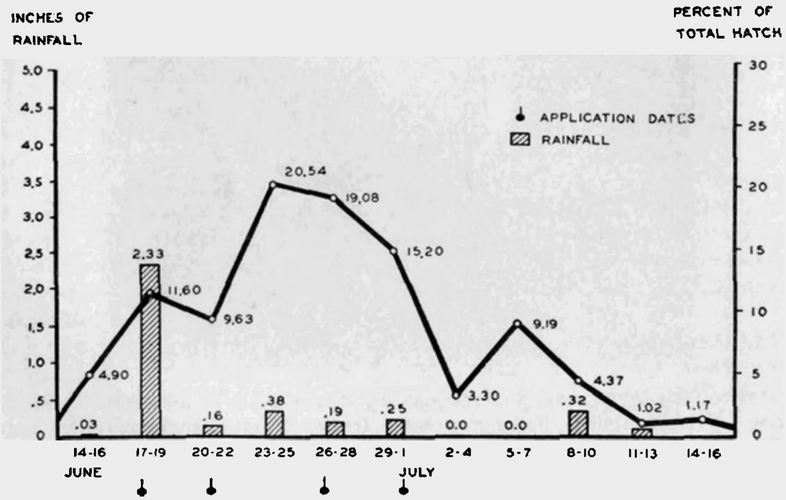

Figure 35. Hatching rate, rainfall, and dates of insecticide applications. June 14 to July 16, 1935.

This was done for the purpose of establishing insecticidal residues in interfoliar spaces of developing whorls and between the husk and the stalk. The importance of maintaining such residues in these locations has been discussed by Batchelder and Questel[1]. Applications were made uniformly and on the same date in each field experiment as scheduled in Table I.

[1]Batchelder, C. H., and Questel, D. D., Insecticidal Control of the European Corn Borer: The Problems Involved and Some Experimental Results. *Jour. Econ. Ent.* 24: 1152-1167, illus. 1931.

The effectiveness of the materials tested was measured at the time of harvesting the green, fresh ears at the roasting-ear stage. It was based upon (a) the number of larvæ surviving treatment as indicated by dissection of the stalks and ears of a 10-plant sample taken from each replicate plot, and (b) the percentage of borer-free ears produced. Both kinds of data have been included in tables accompanying the discussion of the results obtained.

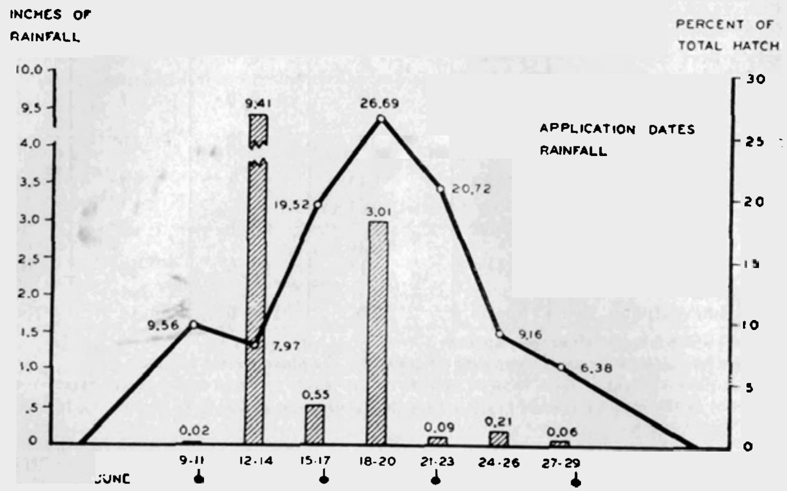

Figure 36. Hatching rate, rainfall, and dates of insecticide applications. June 9-29, 1936.

APPLICATION SCHEDULE

The first treatments were applied when hatching was first observed in the field. Subsequent applications were scheduled at five-day intervals during the period of hatching. The period and the rate of first-generation hatching in the New Haven area during 1935 and 1936 are shown in Figures 35 and 36. In these diagrams the data, in terms of percent of the total number of eggs hatched, are summarized for three-day intervals. Comparison of the hatching periods of 1935 and 1936 indicates the seasonal variation that was experienced in Connecticut. Whereas in 1935 the period of maximum hatching extended from June 17 to July 7, in 1936 it occurred during the period June 10-29. Rainfall, during the period of maximum effectiveness of insecticidal residues, is shown in Figures 35 and 36.

It may be noted that adjustment of the five-day schedule of insecticide applications was necessary, both in 1935 and 1936, on account of rains. Rains not only prevented the application of insecticides on the dates scheduled for the season of 1936, but the occurrence of heavy rains following closely after such applications reduced greatly the period of their effectiveness. All of the materials were subjected to a severe test of their capacity to form rain-resistant residues, and their performance during both 1935 and 1936 should be considered with reference to the rainfall as shown diagramatically in Figures 35 and 36.

It is important to consider the growth stages characteristic of the corn plants at the time of each application. As shown in Table 1, the treatments were applied during a period of rapid growth of the plants. Although

Table 1. Relation of growth stages of Golden Early Market sweet corn to corn borer hatching, and to the dates on which insecticides were applied.

PLANT DEVELOPMENT		1935		1936	
Stages[1]	Height (inches)[2]	Observation dates	Hatching (percent)[3]	Observation dates	Hatching (percent)[3]
Early whorl	10–15	June 1	0.0	May 24	0.0
Early whorl	12–20	10	0.0	June 1	0.0
Late whorl; no tassel showing	20–28	17*	4.9	10*	9.5
Emerging tassel enclosed in leaf-blades	30–40	21*	26.1	17*	37.0
Green tassel; small ears without silk	46–50	26*	61.6	22*	84.4
Pollen shedding; ears silking	55–65	July 1*	80.9	29*	99.0
Dry tassel; ears harvested	55–65	20	100.0	July 14	100.0

*Dates on which insecticides were applied.

[1] Characteristic appearance of more than 50 percent of the plants on the specified date.

[2] Approximate height of more than 50 percent of the plants to tip of topmost leaf-blade.

[3] Percent of the total number of eggs that hatched during the period June 10-July 15, in 1935 and in 1936.

early market varieties of sweet corn are usually infested by the European corn borer during the growth stages noted in this table, the time of occurrence of these stages in Connecticut varies considerably from field to field and from year to year. This is seen in Table 1 when the items of plant-growth stages, the percentage of the eggs hatched, and the application dates of 1935 are compared with corresponding items of the season of 1936. The first-early variety described, Golden Early Market, was planted as early as the seasons permitted in both years. Later plantings of this variety in the same localities would have been in earlier stages of plant growth at the time that hatching occurred and insecticide applications were made.

EVALUATION OF RESULTS OF FIELD-PLOT EXPERIMENTS

The results obtained in field-plot experimentation have been considered with reference to the insecticidal properties of the materials tested. Very definite limitations are imposed upon corn borer insecticides, due both to the nature of the plant and to the habits of the insect. Therefore the preparations investigated were designed for quite specific purposes. Several modifications of each of them were compared in laboratory studies, but only those showing special promise were tested in the field. Several of the materials were retested during 1936, following favorable results obtained in 1935. Their performance in spray or in dust form is discussed in paragraphs to follow, and the data obtained during the field experiments have been summarized in Tables 2, 3, and 4. In these tables it will be noted that in all experiments the items of data referring to reduction of borers in ears and in plants have been derived by comparison of data from treated plots with those from plots receiving no treatment. When materials were applied as sprays, the nicotine tannate standard was also employed in drawing conclusions.

Infestations prevailing in the cornfields used for these studies were typical of the seasons of 1935 and 1936 and were considered adequate for experimental purposes. Examination of corn plants taken from check plots in which no treatment had been applied showed that they contained from 197 to 841 borers per 100 plants while from 31 to 77 percent of the ears were infested. Variations in field infestations from locality to locality, as well as from year to year, are to be noted in the plots receiving no treatment included in each of the tables summarizing experiments.

Table 2. Effectiveness of spray materials applied to early market sweet corn infested with the first generation of the European corn borer in 1935 and in 1936.

Spray materials	Active agent: percent	No. of larvae per 100 plants	No. of borer-free ears per 100 plants	PERCENT OF: Reduction of borers in ears	PERCENT OF: Reduction of borers in plants
Experiments Conducted in 1935[1]					
No treatment	......	682.8	40	0.0	0.0
Nicotine tannate (standard)	0.062-Nicotine	213.2	95	78.6	68.7
Derris extract	.02-Rotenone	190.0	73	71.4	72.1
Ground derris	.018-Rotenone	81.5	103	87.6	88.0
Phenothiazine	.48-Phenothiazine	73.4	106	88.8	89.2
Experiments Conducted in 1936[2]					
No treatment	......	197	105	0.0	0.0
Nicotine tannate (standard)	.062-Nicotine	20	140	87.5	89.8
Ground derris	.02-Rotenone	35	137	87.5	82.2
Phenothiazine	.48-Phenothiazine	15	137	87.5	92.4

[1] Spreading agents: ammonium sulfo soap, 0.075 percent used with derris, rotenone, and nicotine tannate; butyl phenyl-phenol sodium sulfonate, .025 percent used with phenothiazine.

[2] Spreading agent: butyl phenyl-phenol sodium sulfonate, .03 percent.

Nicotine tannate spray was employed chiefly as a standard for comparison in these experiments. Measurements of the effectiveness of this material, as summarized in Table 2, showed that in 1935 it afforded more protection to the ear than to the plant as a whole. In the field tests conducted during 1936 it provided a high rate of protection for the plants as well as a suitably high standard for comparison with other insecticidal materials.

PERFORMANCE OF INSECTICIDES APPLIED AS SPRAYS

Spray preparations of insecticides used in field-plot experiments have been previously described. Their performance is discussed in the succeeding paragraphs and their effectiveness in reducing the number of corn borer larvæ in entire corn plants and in marketable ears is shown in Tables 2 and 3.

Ground Derris and Derris Extract

Ground derris was found to be more effective than an acetone extract of derris when the rotenone content of each of the two sprays was approximately 0.02 percent. The items of Table 2 show that ground derris was more effective than the extract in reducing (a) the number of larvæ in the plants, (b) the number of larvæ in the ears, and (c) the number of ears that were infested. The yield of the borer-free ears in derris-treated plots (84 percent) was sufficiently high to give satisfactory commercial return, whereas the protection afforded by the derris extract (68 percent borer-free ears) was not sufficient. For this reason it appeared more desirable to continue investigation of ground derris than of derris extract. Field experiments with ground derris spray were repeated during 1936, with results as summarized in Table 2, which show that it continued to compare favorably with the nicotine tannate standard as a corn borer insecticide.

TABLE 3. EFFECTIVENESS OF PREPARATIONS OF FIXED NICOTINE APPLIED TO EARLY MARKET SWEET CORN INFESTED WITH THE FIRST GENERATION OF THE EUROPEAN CORN BORER IN 1935 AND IN 1936.

Spray materials	Nicotine content: percent	Number of larvae per 100 plants	No. of borer-free ears per 100 plants	PERCENT OF Reduction of borers in ears	PERCENT OF Reduction of borers in plants
Experiments Conducted in 1935[1]					
No treatment	......	841	42	0.0	0.0
Nicotine tannate (standard)	0.062	291	107	83.2	65.4
Nicotine tannate in alcohol	.062	391	72	56.0	53.5
Nicotine tannate (powder)	.062	350	72	59.5	58.4
Dual-fixed nicotine (powder)	.058	229	102	77.1	72.7
Nicotine bentonite (powder)[3]	.058	184	95	85.9	78.1
Experiments Conducted in 1936[2]					
No treatment	......	411	40	0.0	0.0
Nicotine tannate (standard)	.062	85	80	77.7	79.3
Nicotine bentonite, tank-mixed	.062	124	78	72.0	69.8
Nicotine bentonite (powder)[4]	.062	92	91	67.7	77.6

[1] Spreading agent: ammonium sulfo soap, 0.075 percent
[2] Spreading agent: butyl phenyl-phenol sodium sulfonate, 0.04 percent, except nicotine bentonite concentrate, 0.033 percent.
[3] With zinc oleate sticker.
[4] With petroleum oil sticker.

Phenothiazine

Laboratory and field-plot studies of phenothiazine sprays were conducted during 1935 and 1936. Applied in experimental plots during the season of 1935, they showed insecticidal properties similar to those of ground derris. A comparison of the items of data in Table 2 shows a large increase in the number of borer-free ears and reduction of borer population resulting from the use of phenothiazine spray on early market sweet corn. When retested during the season of 1936, it continued to provide similar protection, being somewhat more effective in reducing the borer population in plants (92 percent) than either derris (82 percent) or the nicotine tannate standard (89 percent). In the field phenothiazine was observed to be no more adhesive than derris. It exhibited the same tendency to accumulate at critical areas on the plant in the presence of moisture and, like derris, it did not appear to be readily washed from the plants by light showers.

Nicotine Tannate Powder

This preparation was employed in 1935 both with a dust carrier and as a spray suspension. As indicated in Table 3, residues of spray applications failed to provide protection to the plants equal to that of the nicotine tannate standard, although both contained the same amount of nicotine. Considerable agitation was necessary to maintain a spray suspension of this material during application and its residues were readily washed off during rains. Nicotine tannate powder was not tested during 1936.

Nicotine Tannate in Alcohol

This preparation dispersed readily when mixed in spray water and apparently required little agitation, but it failed to provide protection to early market sweet corn equal to that afforded by any of the other materials used (Table 3). It was noted that free nicotine was released when sprays were applied, and the conclusion was suggested that its residues were not sufficiently stable to provide continuous protection between spray applications. Studies of this type of nicotine tannate were not undertaken in 1936.

Nicotine Bentonite Powder with Adhesives

A preparation of nicotine bentonite powder with a zinc oleate sticker was studied in 1935 and the material gave a high rate of protection to the crop. However, it was found difficult to keep it in suspension, and neither uniform application nor consistent control was obtained in the plots. A similar dry preparation of nicotine bentonite with 0.024 percent emulsified petroleum oil content was therefore included in the field-plot tests of 1936. This material was readily kept in suspension, its residues were sufficiently adhesive, and the protection obtained was comparable with that of the nicotine tannate standard. Plant injury followed its use, however, and this preparation is therefore considered impractical for general use on sweet corn.

Nicotine Bentonite, Tank-Mixed

This material was found to be very much more adhesive than other spray preparations of nicotine bentonite used in these experiments. Its residues, however, are conspicuous and are likely to affect the marketability of products treated with it. The control obtained following its use has been variable, and, as indicated in Table 3, when applied to early market sweet corn it did not provide protection as high as that of the nicotine tannate standard.

Dual-fixed Nicotine

This combination of the two concentrates of nicotine tannate and nicotine bentonite was used both as a spray and as a dust in field-plot experiments. The results obtained when applied as a spray are included in the 1935 section of Table 3, where it may be noted that the protection provided was comparable with that obtained with the nicotine tannate standard.

PERFORMANCE OF INSECTICIDES APPLIED AS DUSTS

Some of the materials employed in spray treatments were also applied as dusts to adjacent plots in the same fields. Their performance is discussed in succeeding paragraphs and the data showing their effect upon the infesting populations of entire corn plants and of ears are summarized in Table 4.

TABLE 4. EFFECTIVENESS OF DUST MATERIALS APPLIED TO EARLY MARKET SWEET CORN INFESTED WITH THE FIRST GENERATION OF THE EUROPEAN CORN BORER IN 1935 AND IN 1936.

Dust materials	Active agent: percent	Number of larvae per 100 plants	No. of borer-free ears per 100 plants	PERCENT OF Reduction of borers in ears	PERCENT OF Reduction of borers in plants
Experiments Conducted in 1935[1]					
No treatment	......	690.0	23	0.0	0.0
Phenothiazine	3.0-Phenothiazine	410.0	58	51.4	40.6
Ground derris	0.4-Rotenone	253.8	73	74.4	63.2
Nicotine tannate (powder)	4.0-Nicotine	181.5	78	75.6	73.7
Dual-fixed nicotine (powder)	6.0-Nicotine	128.0	113	94.3	81.4
Experiments Conducted in 1936[2] Series 1					
No treatment	......	412	46	0.0	0.0
Talc carrier	......	230	51	15.3	44.1
Ground derris	0.4-Rotenone	105	75	58.0	74.5
Ground derris	0.6-Rotenone	112	68	49.1	72.8
Ground derris	0.8-Rotenone	107	78	62.7	74.0
Experiments Conducted in 1936[2] Series 2					
No treatment	......	401	32	0.0	0.0
Ground cubé	0.8-Rotenone	144	60	37.2	64.0
Nicotine bentonite (powder)	3.2-Nicotine	196	50	41.7	51.1
Dual-fixed nicotine (powder)	3.0-Nicotine	201	62	43.1	49.8
Dual-fixed nicotine (powder)	4.0-Nicotine	102	67	59.0	74.5

[1] Dust adhesive: butyl phenyl-phenol sodium sulfonate, 0.10 percent.
[2] Dust adhesive: butyl phenyl-phenol sodium sulfonate, 0.03 percent.

Phenothiazine Dust

As shown in Table 4, a dust preparation containing 3.0 percent phenothiazine did not provide satisfactory plant protection as compared with other materials used. It gave only 40 percent reduction of the larval population of the plants and 51 percent reduction of the borer population infesting the ears. Extensive plant injuries also accompanied use of the dust preparation employed in these tests. For these reasons experiments with phenothiazine dust were discontinued.

Ground Derris

Ground derris applied to corn in a dust (talc) carrier during 1935 was found to be less effective (63 percent) in reducing the borer population of corn plants than when applied in adjacent plots as a spray (88 percent). It was considered advisable to determine the value of higher concentrations of derris in the dust mixture, and the results obtained with these preparations during the 1936 experiments are summarized in Table 4. In this table it may be noted that (a) the effectiveness of derris dust when the rotenone content was 0.4 percent, 0.6 percent, or 0.8 percent did not increase consistently with the rotenone content and (b) that all of these derris dusts gave a reduction in the borer populations infesting the plants approximating the results obtained with the dual-fixed nicotine (4 percent) dust tested in adjacent plots. In another experiment conducted in adjacent plots, a dust preparation of ground cubé containing 0.8 percent rotenone was found to be less effective insecticidally than dual-fixed nicotine dust (4 percent nicotine). In comparing the performance of dust preparations tested in 1936, however, the frequency and the extent of the rainfall occurring during the critical period of residue effectiveness (Figures 35 and 36) should be considered carefully. It is believed that the effectiveness of all materials was greatly reduced by these rains and that inconsistent results are attributable to residue losses occasioned by them.

Nicotine Dusts

From Table 4 it will be seen that a preparation of dual-fixed nicotine displayed outstanding insecticidal effectiveness in 1935, reducing the number of borers infesting the plants 81 percent and providing a 90 percent borer-free yield. This combination of nicotine tannate and nicotine bentonite was superior to a preparation of nicotine tannate dust which gave 73 percent reduction of the plant infestation and a yield 66 percent borer-free. This difference in insecticidal effectiveness was ascribed to differences in nicotine content as well as to differences in the numbers of active particles present in the two dust preparations. Dual-fixed nicotine dust was therefore tested during 1936 in 3 percent and 4 percent nicotine concentrations. In this experiment dual-fixed nicotine with 4 percent nicotine was more effective insecticidally than when it contained 3 percent nicotine. The material was also found to compare favorably with dust preparations of nicotine bentonite (3.2 percent nicotine) and of cubé (0.8 percent rotenone content). The consistently satisfactory performance of dual-fixed nicotine has indicated it to be the most useful of the dust preparations investigated.

DISCUSSION AND SUMMARY

This is a progress report of investigations that are not complete in all phases. The preparations employed were largely experimental, designed for use against the European corn borer, and had not been used previously in field experiments. Several of the preparations obviously lack physical properties that are highly desirable in corn borer insecticides, but some of these materials may show considerable improvement with further developmental research. This is particularly true of some of the preparations of fixed nicotine. Preparations of derris, phenothiazine, and nicotine tannate in spray form and a dual-fixed nicotine dust provide sufficient reduction in borer populations to warrant their use in field tests to ascertain their value under commercial conditions and practice.

Severe tests of weathering capacity and wash-resistance were imposed upon the materials used in these experiments. During the field experiments conducted in 1935, residues were subjected to frequent rains or light showers, and in 1936 they were again affected by the frequency and also the heaviness of the rainfall.

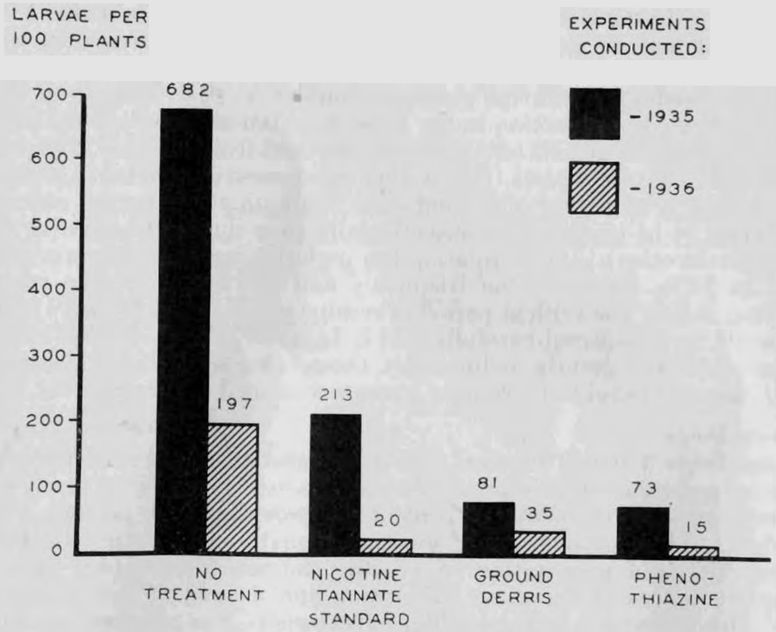

Figure 37. Effectiveness, in terms of borer survival, of spray preparations applied to early market sweet corn infested by the first generation of the European corn borer.

It is entirely possible that some of the preparations which failed to provide adequate protection when employed under conditions prevailing in Connecticut might prove useful as insecticides where rainfall occurs with less frequency. A certain amount of residue mobility, however, is desirable, since re-deposit of the insecticide at lower levels, coincident with plant growth, would insure continued protection of interfoliar spaces. The materials dealt with in field-plot experiments were all highly toxic to larvæ of the European corn borer. That some of them proved more suitable for general use than others may be attributable to their superior physical properties, such as suspensibility, adhesiveness, and proportion of active particles in the residues.

Several of the preparations that have shown outstanding insecticidal effectiveness during these experiments are compared diagrammatically in Figures 37 and 38.

In Figure 37 the effectiveness of three materials applied as sprays is compared on the basis of the number of larvæ per 100 corn plants surviving treatment. While this is not the only criterion employed in comparing these materials, it serves the useful purpose of illustrating differences in availability of the active agents of these preparations to the infesting larvæ. This is also shown in Figure 38, where the three outstanding materials applied as dusts are compared. A striking difference is to be noted when the survival rates occurring in 1935 are compared with those of 1936. This

is attributed to differences in the intensity of the original infestation as well as to differences in residue losses occurring during the critical period of residue effectiveness. The field performance of these preparations is summarized in further detail in the paragraphs to follow.

The attempt to develop a suitable dry concentrate of fixed nicotine which could be prepared in advance of its use as a spray, and stored, was not productive of an insecticide that withstood weathering satisfactorily. This is probably attributable to the loss of desirable physical properties that occurs when these materials are dried and reground. Likewise, a concentrate of nicotine and tannin in alcohol did not provide corn-plant protection equivalent to that of the field-reacted nicotine tannate standard.

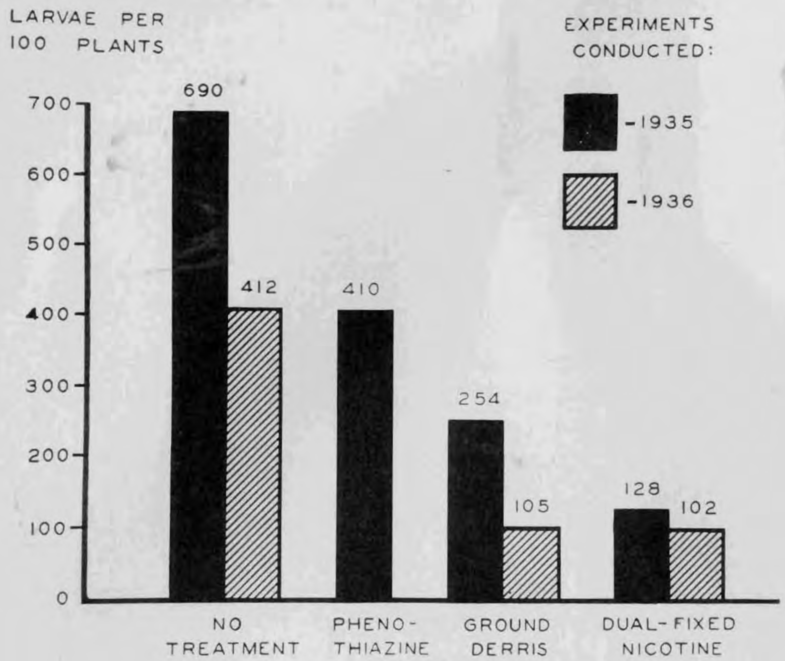

Figure 38. Effectiveness, in terms of borer survival, of dust preparations applied to early market sweet corn infested by the first generation of the European corn borer.

Tests of ground derris spray containing 4 pounds of derris to 100 gallons of water showed consistently satisfactory control when compared with the nicotine tannate standard used in the same spray schedule.

Phenothiazine, when applied as a spray at the rate of 4 pounds per 100 gallons of water, was found to compare favorably with the nicotine tannate standard in reducing the number of borers infesting corn. Two grades of this material were tested in the field experiments, a recrystallized and a technical grade of relatively high purity. Both preparations provided satisfactory protection against corn borer infestation.

Experiments undertaken for the purpose of determining the effectiveness of insecticides applied in dust form showed that the preparations of derris, phenothiazine, and nicotine tannate used were unsatisfactory. However, a newly developed preparation, dual-fixed nicotine, consisting of nicotine tannate and nicotine bentonite, gave a degree of control consistent with commercial requirements.