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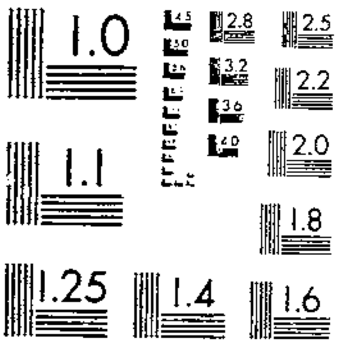

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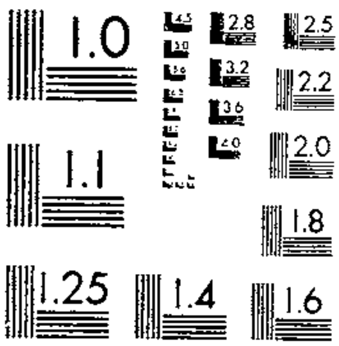

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Mineral Oils, Alone or Combined With Insecticides, for Control of Earworms in Sweet Corn[1]

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SUMMARY

Investigations of the insecticidal control of the corn earworm (*Heliothis armigera* (Hbn.)) in sweet-corn ears, performed from 1935 to 1941, inclusive, are discussed in this bulletin.

[1] Submitted for publication June 13, 1944.

The results of exploratory studies in 1936 showed that a medicinal mineral oil was a promising insecticide for use against this insect in sweet corn, and by the summer of 1937 it was found that oils of this type when applied to the interior silks afforded protection against injury by earworms to a larger percentage of the ears than was obtained by use of any other class of materials.

Although the earliest injections of oil into the interior silks of ears were made by thrusting a specially adapted hypodermic needle through the husk, it was found later that when applied to the silk at the tip of the husk with an ordinary oil can, the oil seeped into the ear almost instantly and dispersed through the entire mass of interior silk. Pump oilers, fitted with an attachment to regulate the dosage delivered per ear, were generally used in the field experiments, and when these are connected with a reservoir of oil, the work of treating the ears on a large scale is carried on more rapidly. A dosage of 0.75 ml. of oil inserted one-half inch into the silk mass is recommended.

Various vegetable oils were used in the early experiments, but it was found that a white mineral oil was as good as the best of the vegetable oils, even when insecticides were added to the vegetable oil.

Use of oils alone showed considerable variation in effectiveness, which was correlated with the husk characters of the ears. When applied to loose interior silks, the oil tended to run through them, but in tighter packed silks it remained as a film about the silk strands, forming a saturated barrier in which small and sometimes larger larvae were killed by being smothered, and through which others could not pass readily to reach the kernels. Since most ears of sweet corn were characterized by rather loose silks, however, a desirably high rate of protection was not usually afforded by the oils alone.

An investigation made for the purpose of finding insecticides that might be combined with mineral oil to increase its effectiveness showed that pyrethrum was useful and that, from the standpoints of effectiveness and costs, 0.2 percent of pyrethrins was the most practicable concentration for commercial use.

Further study of insecticides in oil showed that dichloroethyl ether, at a concentration of 2 percent, was as effective as oil-pyrethrins and was much less expensive.

Although oil-pyrethrins was strictly a contact insecticide, oil-dichloroethyl ether was a fumigant as well. Oil-pyrethrins was found to be more effective when applied to ears having short, loose husks; oil-dichloroethyl ether was more effective in ears having longer, tighter husks. Oils ranging in viscosity (Saybolt) from 125–210 seconds appeared to give the best results.

A number of other insecticidal chemicals were tested as additions to mineral oil, but none offered the advantages of pyrethrum or dichloroethyl ether. Oil-treated ears were sampled by at least 372 persons, who ate the roasting ears and reported on the flavor. No reports were received of residues of oil-pyrethrins, but residues were detected on the kernels of a few ears to which oil-dichloroethyl ether had been applied. Most of the residues were detected by persons having a particularly acute sense of taste, and, in any event, these slight residues were present only on the tip kernels. Observation of commercial applications of oil-dichloroethyl ether indicated that when the treatment was made as recommended, residues were rarely found on the kernels of roasting ears.

When applied to unpollinated silks, mineral oil was found to interfere with fertilization, but since the silks of sweet-corn ears under usual conditions were pollinated during the first few days after silk exposure, applying the oil after pollination had been completed usually overcame this difficulty. Germination of sweet-corn kernels was not appreciably affected by oil treatment.

The mineral oil treatment of sweet-corn ears is commercially practical and profitable. In tests under average growing conditions, usually over 75 percent of the ears were protected by application of oil-pyrethrins to the silks. At the rate of about an acre per day, one man could make the single application needed. No waste of oil through run-off occurred when applications were properly made, and 2 gallons of oil or oil containing an insecticide sufficed to treat the average number of ears on an acre. The equipment developed for treatment was inexpensive, could be assembled by growers, and was not fatiguing to use.

INTRODUCTION

Investigations of the insecticidal control of the corn earworm (*Heliothis armigera* (Hbn.)) in green corn were begun in the summer of 1935 at New Haven, Conn. Each succeeding year field work was continued in Dade or Seminole Counties, Fla., during March, April, and May, and in New Haven County, Conn., or Burlington County, N. J., during July, August, and September. In this bulletin a summary is given of investigations made during the period from 1935 to 1941, inclusive.

The first exploratory studies were planned to find the materials and methods of application that showed the greatest promise of usefulness in protecting corn from the earworm. From the outset the choice of materials was restricted necessarily to insecticides that would not be dangerous to consumers and would not injure the ears in any way or cause changes in their appearance or in the development or flavor of the kernels. Many materials were tried and eliminated. Vegetable oils were first tested in the spring of 1936, and mineral oil was first studied during the summer of that year. By the summer of 1937 it was found that highly refined mineral oils were the most promising of all the materials studied, and since then study of these oils has formed an important part of the investigations. Being colorless, odorless, harmless, and tasteless, mineral oils meet all the requirements of a material for use in earworm control except that they interfere with fertilization of the kernels if applied to unpollinated silks. It was found, however, that this difficulty could be overcome by delaying applications until after fertilization had occurred. Brief descriptions of the results of oiling have been published by the author (*2, 3, 4*),[2] and an unpublished bibliography prepared by J. S. Wade on the use of oil on the silk of sweet corn, up to and including 1941, contains a list of 42 titles.

Pyrethrum was first used with oil during the spring of 1937, and by the summer of 1939 the results had shown that the addition of a small quantity of pyrethrum extract to mineral oil (*5, 6*) increased its effectiveness considerably.

In 1939 dichloroethyl ether was found to be an inexpensive substitute for the more costly pyrethrum (*7, 18*).

[2] Italic numbers in parentheses refer to Literature Cited, p. 82.

In 1938 Pepper began to investigate the oiling method of earworm control in New Jersey (*16, 17*), and in 1939 Carruth began to study this method in New York (*9, 10*) and Michelbacher (*15*) in California. A few tests were made elsewhere by Bailey (*1*), Cartwright (*11*), Ditman et al. (*13*), Fisher and Shull (*14*), the Delaware Agricultural Extension Service (*12*), and Webster and Eichmann (*19*). By 1941 a considerable number of investigators were testing the method in many sections of the country.

The first commercial oil-pyrethrum mixture prepared especially for earworm control was offered in 1940, and in 1941 several such preparations and also commercial preparations of oil-dichloroethyl ether were available to growers of sweet corn. Special applicators were available commercially in 1940.

The mineral-oil treatment was used commercially beginning in 1940, and by 1941 it had become a standard practice with progressive growers of large acreages of sweet corn. This was particularly true in the Coachella Valley, Calif., as reported by Wilcox (*20*).

FACTORS AFFECTING EARWORM CONTROL

Preliminary investigations gave no encouragement to a belief that corn ears could be protected against earworms by applications of dusts or sprays to the exterior silk mass. The writer (*8*) showed that the newly hatched larvae fed very little exteriorly, that many had already gained access to ears by the time dusts or sprays were applied, and that the structure of the corn ears was such that dusts and sprays would not penetrate readily into the interior silk of most ears, where the larvae begin to feed. Corn silks are provided with a waxy coating and with innumerable short hairs, and, except in the case of ears having loose husks, the silk strands usually are pressed together at the tip of the ear where they emerge and for some distance within the ear. The result is that the short hairs interlock to form a sieve, and this and the waxy coating serve to repel rain and form a barrier against penetration by dusts and sprays. Since a knowledge of the habits of earworms after they have entered the ears was needed in order that the problem might be attacked intelligently, many series of ears were examined, and the results of some of these examinations are given under subsequent headings.

Increase and Decrease of Larvae in Ears

Ears of the variety Snowflake grown in Dade County, Fla., in March 1936 were tagged before the silks were exposed. Series of these ears were examined each day from the fourth to the twenty-first day after silk exposure, and the findings are summarized in table 1. Most of the larvae had entered the ears during the first 8 or 9 days after silking.

Examinations of ears of Golden Cross Bantam sweet corn and local, white sweet corn at Masonville, N. J., in August 1938 (table 2) showed that earworm populations remained rather constant in the ears of the first variety during the first 10 days after silking, but that in ears of the second variety the numbers rose until the sixth day and began to fall by the eighth day after silk exposure.

TABLE 1.—*Location of earworms in ears of the corn variety Snowflake from the fourth to the twenty-first day after silk exposure, Dade County, Fla., 1936*

Time after silking (days)	Ears examined	Larvae per ear	Larvae		Larval instar					
			In silks	On kernels	1	2	3	4	5	6
	Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
4	25	1.2	100.0	0.0	80.0	20.0	-------	-------	-------	-------
5	25	1.6	100.0	.0	85.4	12.2	2.4	-------	-------	-------
6	25	2.0	100.0	.0	69.4	20.4	8.2	2.0	-------	-------
7	25	4.1	100.0	.0	58.3	33.0	5.8	2.9	-------	-------
8	25	3.6	100.0	.0	50.5	30.8	11.0	7.7	-------	-------
9	25	5.2	100.0	.0	51.5	27.7	14.6	4.6	1.6	-------
10	25	4.8	99.2	.8	42.0	32.0	16.8	7.6	.8	0.8
11	25	4.9	96.7	3.3	24.6	42.6	21.3	11.5	-------	-------
12	25	5.3	100.0	.0	31.1	35.6	22.0	9.8	1.5	-------
13	25	4.8	100.0	.0	16.5	29.8	28.9	16.5	7.4	.8
14	24	5.9	95.7	4.3	17.7	33.3	24.8	13.5	9.2	1.4
15	25	5.1	85.9	14.1	6.3	20.3	29.7	25.8	15.6	2.3
16	24	4.2	82.0	18.0	-------	9.0	21.0	48.0	18.0	4.0
17	25	4.1	86.2	13.8	-------	3.9	26.5	51.0	16.7	1.9
18	25	3.2	75.0	25.0	1.3	2.5	11.3	33.7	43.7	7.5
19	24	2.9	71.4	28.6	-------	1.4	4.3	24.3	47.1	22.9
20[1]	10	2.4	62.5	37.5	-------	-------	-------	4.2	66.6	29.2
21	10	2.0	60.0	40.0	-------	-------	5.0	15.0	45.0	35.0

[1] Harvest of roasting ears began on this date and some of the tagged ears were taken by the grower.

TABLE 2.—*Occurrence of earworms in ears of 2 varieties of sweet corn on the fourth, sixth, eighth, and tenth days after ears exposed silks, Masonville, N. J., August 1938*

[Ears with fresh silks were tagged on August 5; 25 ears were examined per field on each date]

GOLDEN CROSS BANTAM SWEET CORN

Time after silking (days)	Ears infested	Total larvae found	Number of larvae found in silks in instars—							Number of larvae found on kernels in instars—							Larvae on kernels	Ears infested in kernels
			1	2	3	4	5	6	Total	1	2	3	4	5	6	Total		
	Number	*Number*															*Percent*	*Percent*
4	23	44	6	10	8	7	1	1	33	---	2	3	6	---	---	11	25.0	34.8
6	21	40	---	3	9	4	2	---	18	---	---	9	9	2	2	22	55.0	76.2
8	25	44	---	---	4	4	2	---	10	---	---	8	14	7	5	34	77.3	88.0
10	25	38	---	---	1	2	3	1	7	---	---	--	6	18	7	31	81.6	96.0

LOCAL, WHITE SWEET CORN

Time after silking (days)	Ears infested	Total larvae found	Silks 1	Silks 2	Silks 3	Silks 4	Silks 5	Silks 6	Silks Total	Kernels 1	Kernels 2	Kernels 3	Kernels 4	Kernels 5	Kernels 6	Kernels Total	Larvae on kernels	Ears infested in kernels
4	22	30	11	17	5	2	2	---	37	---	1	1	---	---	---	2	5.1	9.1
6	22	41	4	9	17	5	1	1	37	---	---	2	2	---	---	4	9.8	18.2
8	19	34	---	3	6	11	---	---	20	---	---	5	6	2	1	14	41.2	52.6
10	24	32	---	---	2	3	2	---	7	---	---	5	10	9	1	25	78.1	79.2

An examination of ears of Golden Cross Bantam in three stages of development in Dade County, Fla., in 1939 showed an increase of larvae from 3.1 per ear having fresh silks to 6.1 per ear having wilted silks, and 9.7 per ear having partly browned silks. These three stages of growth (table 3) represented roughly the second, fourth, and eighth days after silk exposure. The general results of these and other examinations showed that earworms entered the ears continuously during the first week or more following silk exposure, and indicated that a control measure directed against the larvae while they were feeding in the interior silk would affect the greatest numbers if applied not earlier than 1 week after silk exposure.

TABLE 3.—*Penetration of earworms of different instars into ears of Golden Cross Bantam sweet corn at 3 stages of growth, Dade County, Fla., 1935*

[25 ears of each stage of growth were examined]

Instar	Larvae found	Larvae of stated instars that had penetrated into ears for indicated distances (inches) below tip of husk							Average distance penetrated per larva
		0-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.0	6.0-6.9	
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Inches*
EARS WITH FRESH SILKS—TOO YOUNG TO OIL									
First	52	57.7	42.3						0.94
Second	21	38.1	47.6	14.3					1.21
Third	4	50.0	25.0	25.0					1.78
Total or weighted average	77	51.0	42.9	5.2					
EARS WITH WILTED SILKS—RIGHT STAGE TO OIL									
First	68	39.7	52.9	5.9	1.5				1.19
Second	48	39.6	50.0	10.4					1.21
Third	23	21.7	39.1	26.1	8.7	4.4			1.79
Fourth	12	8.3	41.7	41.7	8.3				2.04
Fifth	1					100.0			4.90
Total or weighted average	152	34.2	48.7	13.2	2.6	1.3			
EARS WITH PARTLY BROWNED SILKS—TOO OLD TO OIL									
First	10	60.0	40.0						1.15
Second	16	12.5	81.3	6.2					1.29
Third	76	19.7	50.0	19.7	7.9	2.6			1.61
Fourth	98	14.3	21.4	21.4	15.3	22.4	5.1		2.72
Fifth	37	2.7	16.2	10.8	29.7	21.6	16.2	2.7	3.58
Sixth	5					60.0	20.0	20.0	5.08
Total or weighted average	242	15.7	33.9	16.9	13.2	14.5	4.9	0.8	

STAGES OF GROWTH OF LARVAE IN EARS

The normal development of a larva that hatches from an egg deposited on the fresh silk of an ear, enters the tip immediately, and feeds continuously within the ear first entered, covers a period of about 2 weeks in midsummer. As shown in tables 1, 2, and 3, newly hatched larvae may continue to enter the ear for 1 or 2 weeks after the silks have appeared, and several or all six instars may be found in ears by the time the silks have begun to turn brown. The data in table 1 show that third instars were present in the ears beginning on the fifth day after silking, that fourth instars first appeared on the sixth day, fifth instars on the ninth day, and sixth instars on the tenth day after silking. The data of table 2, however, show that sixth instars were present in ears of Golden Cross Bantam 4 days after silking, and in local white sweet corn on the sixth day after silking. Evidently not all larvae that enter the ears have hatched on the silks. Particularly when the insect is abundant, eggs are laid elsewhere than on the silks during a period of several weeks before silk exposure, and larvae of all stages of development may migrate to and enter the ears as soon as the silks are exposed. Thus a control measure directed against the larvae after they have entered the ears must be effective against all instars if a high percentage of the ears are to be protected.

Rate of Penetration of Larvae Into Ears

The newly hatched earworms settle to feed in the interior silk mass, usually near the tip of the husk, penetrate toward the cob, and usually reach the kernels by the time they are in the fifth or sixth stadium. It is while the larvae are of these two instars that they consume the greatest amount of food and cause most of the damage to the ears. The rate of penetration of the larvae into the ears and the stage of growth they attain before reaching the kernels depend largely on certain characters of the ears. Since some of these characters are very important in relation to the degree of control obtained in different fields and varieties of sweet corn by use of oil insecticides, they will be discussed briefly.

EFFECT OF HUSK TIGHTNESS

The rate of penetration by earworms into corn ears depends in part on whether they can crawl between the silk strands. If these strands are pressed together firmly by the husks the progress of the larvae is slow, sometimes being limited by their ability to eat their way inward; whereas if the silks are held loosely the larvae may penetrate the silk more rapidly by crawling between the strands. Since feeding and penetration toward the kernels are concurrent, the larger instars usually are found to have penetrated progressively farther into the ears. This and the average penetration are shown in table 3 for Golden Cross Bantam, a variety with loose husks.

Larvae of various instars penetrate much less rapidly into ears of Snowflake, in which the husks press the silk strands firmly together. In ears of Snowflake only 6.7 percent of the larvae had penetrated from 1½ to 2 inches below the husk tip, whereas in ears of Golden Cross Bantam at about the same stage of growth (ears with partly browned silks) 50.3 percent of the larval population had penetrated for 2 inches or more. In ears having tight husks the larval population is concentrated for a longer time relatively near the husk tip than in ears having loose husks, and can be reached much more easily by insecticides that are applied to the tip of the ear.

EFFECT OF HUSK LENGTH

In ears of different varieties, and in different ears of any one variety of sweet corn or roasting-ear corn, the husks extend for different distances beyond the cobs. Not only the tightness but also the length of the husk is important. It often happens that the long husks are also relatively tight and that the short husks are unusually loose. In two varieties having husks of approximately equal tightness, larvae reached the kernels in 21.5 percent more ears of the variety having shorter husks and had caused serious injury in 18.8 percent more ears than in the longer husked variety.

In a variety having tight husks of medium length, one with long, loose husks, and one having short and comparatively loose husks, 46.4 percent of the larvae reached the kernels in ears having tight husks of medium length (Tuxpan); 62.9 percent reached the kernels in ears having long, loose husks (Kancross); and 69.2 percent reached the kernels in ears having short, loose husks (Golden Cross Bantam), by roasting-ear harvest. It is thus apparent that when larvae can crawl among the interior silk strands rather freely because the strands are loosely pressed by the husks, they may reach the kernels in almost the same numbers and nearly as soon in long-husked ears as in shorter husked ones, especially if the husks of the latter are somewhat tighter; and if the husks are tight, extremely long husk development is somewhat of a hindrance in reaching the larvae effectively with insecticides.

On the other hand, husks that extend from 2 to 3 inches beyond the cob at time of roasting-ear harvest are very desirable, particularly if rather tight, for comparatively thorough distribution of an insecticide can be obtained in the moderate-sized mass of interior silk of such ears, and the larvae, which penetrate more slowly, can be reached by the insecticide and destroyed before they reach the kernels.

TIME WHEN LARVAE REACH KERNELS

Although larvae were found on the kernels of Snowflake corn beginning on the tenth day after silking (table 1), they did not begin to reach them in important numbers until the fifteenth day, and even on the twenty-first day only 40 percent had reached the kernels. Only 5.1 percent of the larvae in a local white variety, as compared with 25 percent of the larvae in Golden Cross Bantam ears, had reached the kernels by the fourth day after silking (table 2), and only 78.1 percent in the local white, as compared with 81.6 percent in Golden Cross Bantam, had reached the kernels by the tenth day. It appears, therefore, that the stage of growth of corn ears when larvae reach the kernels is extremely variable as between different varieties of corn, and is governed by the rapidity of penetration, which in turn is influenced by the tightness of the husks about the silks and cobs. The husks of most sweet-corn varieties are comparatively loose, larvae disperse rapidly within them, and if control measures are to be highly effective in these varieties they must be applied relatively soon after silk exposure.

EFFECT OF DROUGHT

Those parts of the plants that develop during dry periods are stunted, and moisture conditions during the time the ears are developing have an important relationship to the rapidity with which larvae reach the kernels, the amount of injury they cause, and the effectiveness of control measures. This effect is particularly noticeable in the case of the husks, which during dry periods often are found to be shorter, looser, and more flaccid than usual. Under these conditions the larvae disperse more rapidly and reach the kernels sooner than in normal ears, and small larvae sometimes even penetrate to the kernels on the middle of the cobs. Owing to their more rapid dispersion the larvae are less likely to compete, and mortality by cannibalism may be reduced, resulting in a higher rate of survival. The wider and more rapid dispersion of the larvae makes it more difficult to reach many of them with insecticides applied to the tips of the ears, and fewer ears can be protected against injury when this method is used.

INJURY TO EARS OF DIFFERENT VARIETIES OF SWEET CORN

The previous discussion has indicated that ears of sweet corn having different characters, especially in regard to the husks, would be infested differently by earworms when grown under the same conditions and exposed to similar populations of the insect. That this is true is shown in the data given in table 4, in which the rates of infestation and injury to the kernels of 10 varieties of sweet corn, as compared with ears of a variety of roasting-ear corn, are summarized. Under the conditions of Dade County, Fla., where injury to the kernels occurs in nearly all ears of sweet corn, the percentage of ears injured for over 1 inch ranged from 64 in Stowell's Topcross to 100 in Seneca 60.

TABLE 4.—*Location of earworm injury in sweet-corn ears in relation to the character of the husks; check (untreated) ears used in oiling experiments, examined at time of roasting-ear harvest; Dade County, Fla., March 1939*

Variety [1]	Ears examined	Ears at harvest time in which feeding by earworms was found: Uninfested at harvest time	In the silk	In the kernels for a distance below cob tip of— 1 inch or less	1.1 to 2 inches	More than 2 inches	Total larvae	Larvae per ear
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Number*	*Number*
Tuxpan [2]	60	3.33	41.67	15.00	38.33	1.67	130	2.17
Connecticut Experimental Hybrid	25	0	4.00	8.00	76.00	12.00	85	3.40
Kancross	25	0	0	16.00	76.00	8.00	90	3.60
Oregon Evergreen	25	0	12.00	8.00	68.00	12.00	57	2.28
Redgreen	25	0	0	16.00	76.00	8.00	65	2.60
Bantam Evergreen Hybrid	25	0	4.00	16.00	32.00	48.00	67	2.68
Stowell's Topcross	25	0	4.00	32.00	40.00	24.00	88	3.52
Senecross	50	0	0	2.00	56.00	42.00	203	4.06
Seneca Golden	60	0	0	11.67	63.33	25.00	266	3.77
Seneca 60	50	0	0	0	50.00	50.00	147	2.94
Golden Cross Bantam	350	0	0	1.46	64.00	30.64	1,261	3.51
All sweet corn	690	0	.80	7.17	62.18	29.75	2,329	3.42
Total percent sweet-corn ears injured in stated parts			100.00	99.10	91.93	29.75		

[1] The varieties are arranged roughly according to length and tightness of husks, those at top of list having the longest and tightest husks and those at bottom the shortest and loosest husks.
[2] A field corn grown for roasting ears, having very tight, medium-long husks.

INFESTATION OF EARS AT TIME OF HARVEST

Green ears usually are harvested about 3 weeks after silking, at which time the larvae that entered them as newly hatched individuals during the first week after silk exposure are beginning to become full grown and to leave them. Not all the larvae in the ears have reached the kernels, and only part of them have become large enough to cause serious damage. Since larvae of the sixth, or last, instar devour several kernels daily, one large individual may cause objectionable damage to an ear. Depending on populations of larvae and on the type of ears, particularly with regard to husk type, the damage to sweetcorn ears at time of roasting-ear harvest ranges from no injury to the kernels to practically complete destruction of an ear.

Figure 1, *A*, shows an ear that received earworm injury to kernels less than 2 inches below the cob tip by the time of roasting-ear harvest; figure 1, *B*, an ear that received injury extending more than 2 inches below the cob tip; and figure 2, an ear that was completely destroyed by earworms.

Infestation in Ears of Different Ages in One Field

In general, earworm infestation is rather uniform in any field of corn irrespective of the acreage, as the moths deposit their eggs singly on the silks at random through the field. The average number of

Figure 1.—Ears of sweet corn in which earworms have injured the kernels: A Less than 2 inches below the cob tip; B, more than 2 inches below the cob tip. New Jersey, 1941.

eggs laid per female is about 3,000, and individual moths may deposit as many as 500 per night; hence as few as 3 or 4 females may oviposit on as many ears as are ordinarily produced on an acre of corn. When the moths are numerous, as is often the case in the Southern States, only an occasional ear escapes, regardless of when the silk is exposed. In the Northern States this is true usually only in the fall, when an increasing population of the insect concentrates in a decreasing acreage

FIGURE 2.—Ear of sweet corn in which earworms have almost wholly devoured the kernels. Dade County, Fla., 1938.

of corn in the silking stage. At other times a variable but often small percentage of ears is attacked, and the rate of infestation may be quite different in ears of different ages in one field, depending on the numbers of moths that were depositing eggs when the silks were being exposed. For example, in a field of local white sweet corn at Beverly, N. J., examined on July 4, 1938, the infestation in ears past, at, or younger than roasting ear stage was 84, 54, and 20 percent, respectively, indicating that the moths were plentiful when the earliest silks appeared but had become scarce by the time the latest silks were being exposed. A knowledge of this factor helped to determine the experimental methods employed in testing insecticide effectiveness.

METHODS OF STUDY

The methods of study used throughout these investigations were adopted because they seemed best suited to the particular problem involved. Commercial plantings of corn on farms were used throughout, thus allowing a selection of fields carrying suitable infestation, which would have been lacking in rigid plot set-ups where suitable infestations might not occur. In the seven seasons when studies were made in the Northeast, and in the six seasons in Florida, infestations approaching 100 percent were usually present, except for the summer of 1940, when infestations were at a much lower rate.

The experiments were repeated in fields of different varieties grown in different seasons of the year, in several years, in different geographical areas under widely different environmental conditions, and under different levels of earworm population. Materials or methods that gave favorable results under all these conditions were believed to be worthy of commercial trials. Occasionally, treatments that gave good results under conditions of lower population levels in the Northeast failed under conditions of higher population levels in Florida, or the reverse was true.

In any series of experiments in a given field, ears of uniform age, usually judged by the condition of the silks, were selected, treated, and tagged. This selection made it probable that the ears would be rather uniformly infested and that the period from treatment to roasting-ear harvest would be about the same. A given treatment was usually given by one application only, to series of ears in one row, replications sometimes being made in the same field. Although treated ears were thus exposed to subsequent attack by larvae that migrated to them from untreated ears, this defect was of minor consequence and tended to minimize rather than exaggerate the effects of the treatment.

Examination of the ears usually was made when the growers began to harvest the ears as green corn. The husks were opened sufficiently to expose the kernels for a distance of 2 or 3 inches from the tip of the cob. The records made consisted not only of the effect of the insecticide on the ears, such as discoloration, burning, rotting, or objectionable residues, and the degree of freedom of the ears from kernel injury; but also often included the husk extension, the degree of infertility of the kernels at the tip of the cob, the instar, location, and fate of each larva found in the ear, and whether the flavor of the kernels had been altered in any way.

Equipment Used for Applying Oil

The equipment used consisted of apparatus that is readily available and assemblies that can be made inexpensively by growers.

In the earliest work, oil was applied by a "needle nozzle," which was thrust through the husk to reach the larvae where they were feeding in the interior silk. After it was found that oil dispersed almost instantly through the interior silks of corn ears when it was dropped on the exterior silks at the tip of the husk, ordinary oil cans were used, the oil being ejected by pressure on the bottom. In the spring of 1938 force oilers, of which many kinds were available, were found to be satisfactory applicators because the dosage ejected per trigger squeeze could be controlled mechanically, and later a "knapsack" assembly was used.

FORCE OR PUMP OILERS

Oilers provided with internal force pumps, that eject a dosage of oil by pressure on a trigger and are handled like a pistol, have been found most satisfactory for use in applying oil to sweet-corn ears. Such oilers have been available in a variety of types and size. Some are provided with devices that measure the ejection per trigger squeeze, but if not equipped with such a device they can usually be provided with attachments that enable rough measurements of the ejections to be made. A number of those that have been tried are shown in figure 3.

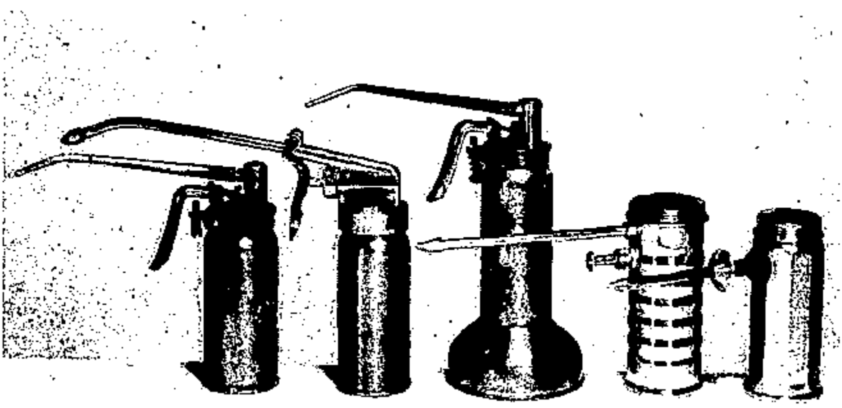

Figure 3.—Types of force or pump oilers that have been used for applying mineral oil to sweet-corn ears.

The writer has used the oiler shown at the extreme left during 4 years, and it gave reasonably accurate ejections per trigger squeeze during the entire time. This type of oiler can be handled for long periods without tiring or blistering the hands, and practical growers have found it satisfactory for treating large acreages.

In actual practice the oil was applied by farm workers at different points on or in the ears, sometimes in such a way that most of the dosage ran off outside. At other times the spout of the oiler was inserted into the interior silk mass for various distances before the oil was released, occasionally so deep within the silk that the larvae feeding nearer the tip of the husk were unaffected. To regulate this a metal disk, such as a washer, of suitable diameter, soldered on the spout of the oiler about one-half inch from its tip as shown in figure 5, stopped the spout at the proper distance.

SPECIAL OILER NOZZLES

When force oilers were used, the oil was delivered at only one spot, either at the tip or within the interior silk of the ear. It was thought possible that distribution of the oil within the interior silk might be more effective. Interchangeable nozzles, therefore, as shown in

FIGURE 4.—Perforated oiler nozzles used in experimental application of mineral oil to sweet-corn ears for earworm control.

figure 4, were prepared for use on the oiler shown at the extreme left in figure 3, the tip of the spout of which has been slightly loosened to show the point of connection. The experimental nozzles mentioned were made of brass tubing of suitable diameter, and 1, 2, or 3 inches long. Their tips were closed and they were provided with 4, 6, or 8 openings, respectively, arranged in a spiral as shown, through which the liquid was forced in all directions. Series of ears of Kancross sweet corn, a variety having husks that extend beyond the cobs for unusually long distances, were treated with white oil of 125–135 seconds viscosity, used alone or containing 0.1 percent of pyrethrins, the nozzles being inserted for their full lengths into the interior silks of the ears before the dosage of 0.7 ml. per ear was discharged. These experiments seem to show that the use of the special perforated nozzles resulted in no more satisfactory protection against injury by earworms than that obtained by use of the ordinary oiler spout. In a second trial, in which applications were made to Golden Cross Bantam ears at dosages of 0.7 or 1 ml. per ear, similar results were obtained.

Openings were then made in the extremity of the 1- and 2-inch nozzles, and in addition they were provided with 8 or 12 openings, respectively, arranged in a spiral, or double the number of openings that had been provided during the first tests. White oil of 125–135 seconds viscosity containing 3 percent of dichloroethyl ether was applied by thrusting the nozzles into the interior silks of Golden Cross Bantam ears before injecting a dosage of 0.75 ml. per ear. No more effective earworm control was obtained than when oil was delivered at one spot in the silk mass. It appeared from the results of these tests that oil distributes itself just as thoroughly within the interior silk of treated ears of sweet corn when injected at one spot in the silk mass at or near the tip of the husks as when delivered at several points within the silk, and kills an equal percentage of the larvae.

KNAPSACK ASSEMBLY

The capacity of the force oilers shown in figure 3 was usually not more than half a pint, and it was necessary to refill them frequently. Oilers of greater capacity were not practical, as they proved much too tiring to handle; hence the half-pint or smaller oilers were attached to supply tanks of at least 1-gallon capacity, holding a half-day's

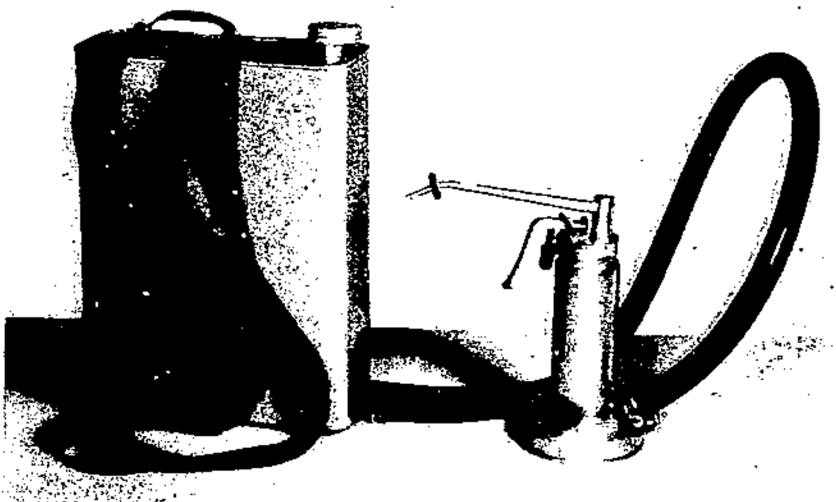

FIGURE 5.—Knapsack assembly of force oiler attached by hose to a storage tank designed to be slung over one shoulder, or worn on the back. Oil feeds from the tank to the oiler by gravity. The oiler is provided with a set screw mounted under the trigger, the adjustment of which regulates the dosage delivered per trigger squeeze. An iron washer has been mounted on the spout of the oiler to regulate the distance the tip can be inserted into an ear.

supply of oil. This was done, as shown in figure 5, by connecting the oiler to a 1-gallon oil can by means of a section of hose about 2½ feet long clamped over short sections of brass or iron pipe that had been soldered into the bottom of the supply can and into the oiler as shown. When the supply tank was slung over one shoulder by means of a strap, or worn on the back like a knapsack, oil flowed by gravity from it into the oiler, which was kept full. The two oilers shown to the right in figure 3 proved more practical for this assembly than the others, since there was no leakage of oil from them.

A modification of this equipment, and one that sometimes may be more convenient, is the belt carriage, or sling, shown in figure 6. It was first suggested by H. A. Whitwood, of Hall, N. Y. This equipment is especially adapted for treatment of sweet-corn ears that are knee high, such as occur when the corn plants have been stunted by dry weather or adversely affected by other factors.

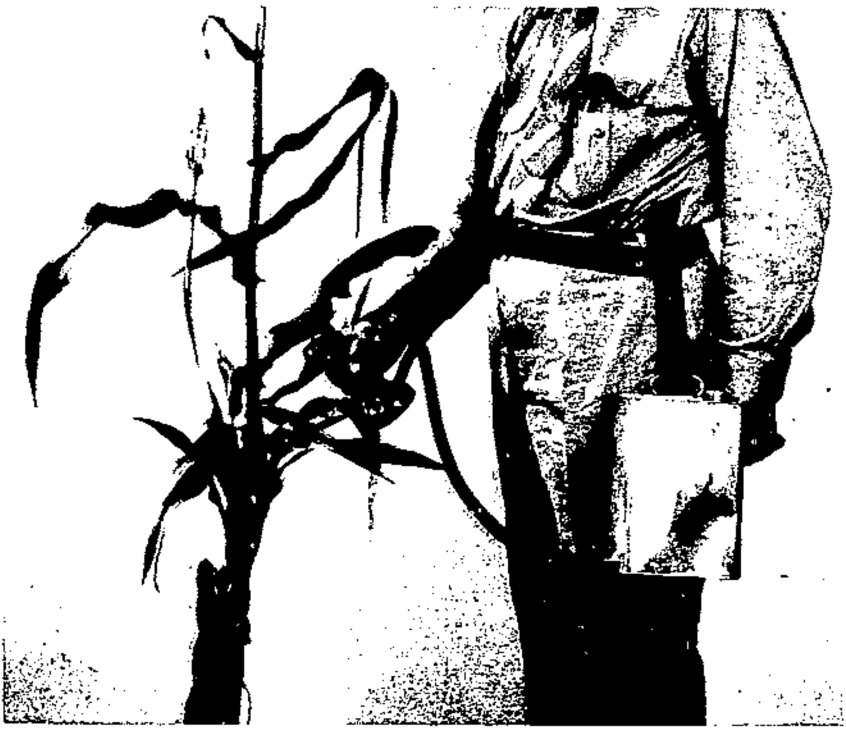

FIGURE 6.—Belt sling of knapsack assembly designed for convenience of carriage, especially when sweet-corn ears are low on the plants.

MARKING OF TREATED EARS

When more than one trip through a field of sweet corn is required in order to treat a suitably large percentage of the ears, it becomes necessary to be able to recognize those that have been treated previously so that a further dosage will not be applied to them. This is particularly true when oil-dichloroethyl ether is used, because, if applied when the ear is well advanced, the chemical may not entirely evaporate from the ears before the time of roasting-ear harvest, leaving undesirable residues that may be detected by consumers.

Several methods of marking treated ears have been suggested and tried by growers. Sometimes the tassels of plants whose ears have

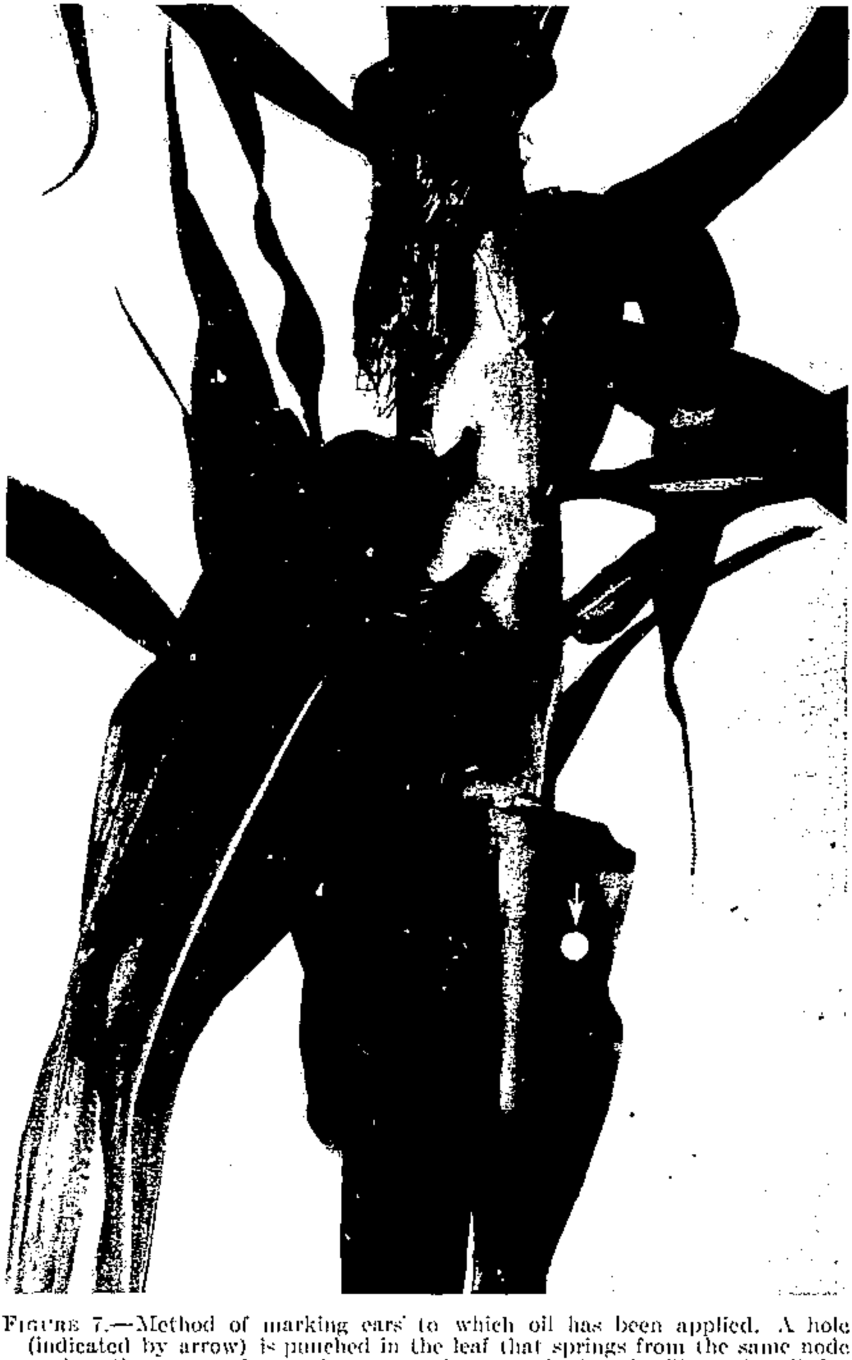

FIGURE 7.—Method of marking ears to which oil has been applied. A hole (indicated by arrow) is punched in the leaf that springs from the same node as does the ear, so that such ears can be recognized and will not be oiled a second time when later developing ears are treated.

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been treated have been broken over so as to be recognized on subsequent trips through the field, but this is not practical when the plants bear two ears of different ages that need treatment at different times. Another method consists of punching a hole of easily recognizable size in the large leaf that springs from the same node as does the ear, and which covers its shank, as shown in figure 7. When the equipment shown in figures 5 and 6 is used for applying oil, the oiler may be carried in the right hand, the left being free to carry a suitable punch with which the treated plant can be marked with little loss of time.

Probably the most satisfactory method of marking treated ears is to use paint or crayon. The use of paint was developed by practical growers in California, where this method of marking is followed rather extensively. A small paint can is equipped with loops so that it can be worn on the belt. A cloth pad is placed in the bottom of the can and sufficient thin, red paint to wet the pad is added. The worker wets the thumb of the left hand with paint and grasps the ear to be oiled with that hand to steady it as the oil dosage is delivered. The thumb mark of red paint left on the husk not only serves to mark the treated ear conspicuously, but it enables the purchaser of green corn to recognize ears that have been treated and protected against earworms. In some markets protected ears are recognized as the highest grade of green corn and are identified by these paint marks by the purchasers.

VEGETABLE OILS USED ALONE

In the spring of 1936 a series of materials were injected into the interior silks of ears of Snowflake corn in a field at Homestead, Fla., by use of a graduated syringe, to determine whether a barrier could be established in the silks that would prevent larvae from penetrating to the kernels. Among the materials studied were three vegetable oils. This was the first test of oil as a means of protecting corn ears against injury by earworms.

In these first experiments 2 ml. of castor oil, cocoanut oil, or refined cottonseed oil were injected into ears through the side of the husk and about 2 inches below the tip, about a week after silk exposure, when the silks were beginning to turn brown. Examination of 10-ear samples at time of harvest about 2 weeks later showed that the average larval population of untreated ears was 4.9 per ear. In ears treated with castor oil it was 3.7; with cocoanut oil, 1.7; and with cottonseed oil, 1.6 per ear. The results in ears treated with cocoanut and cottonseed oils compared favorably with the results of treatment with any other class of materials studied.

During August 1936 evaluation of oils was continued under controlled laboratory conditions. Sweet-corn ears bearing fresh silks were taken from a cornfield in which no earworm infestation occurred. These ears, in lots of 25, were impaled, each on a nail driven through a board about 3 feet long by 8 inches wide, so that the ears stood upright, as on the plants, and did not come in contact with one another. On August 7 two newly hatched earworms were liberated on the silks of each ear. These larvae crawled immediately into the interior silk, where they began to feed. On August 14, oils were injected into the interior silks of each ear by thrusting a needle nozzle through the husk about 1 inch below its tip. The nozzle

(U. S. Patent 2116591, May 10, 1938) consisted of a hypodermic needle soldered to a section of brass pipe bearing a shut-off valve at the opposite end and was connected to a pressure tank. The oils used (table 5) consisted of 9 vegetable oils and 1 medicinal mineral oil.

TABLE 5.—*Effect on the corn earworm of injections of oils into artificially infested sweet-corn ears by use of a needle nozzle; ears infested Aug. 7, oil applied Aug. 14, ears examined Aug. 21; New Haven, Conn., 1936*

Oil used	Ears used	Ears infested when examined	Larvae found per ear	Larvae found in silks		Larvae found on kernels		Larvae found dead	Ears without living larvae
				Alive	Dead	Alive	Dead		
	Number	*Percent*	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*	*Percent*
Coconut	25	92.0	1.2	1	12	18	0	38.7	20.0
Castor	26	92.3	1.3	5	4	26	0	11.4	3.8
Cottonseed	26	88.5	1.1	4	5	17	3	27.6	15.4
Olive	22	95.5	1.5	2	9	20	1	31.2	13.7
Corn	24	95.8	1.3	[1] 1	6	21	0	19.4	4.2
Peanut	25	92.0	1.2	0	7	13	10	56.7	40.0
Linseed	24	83.3	1.3	[1] 2	8	14	8	50.0	29.1
Soybean	24	87.5	1.2	2	5	17	4	32.1	20.8
Tung	25	92.0	1.3	[1] 6	6	17	4	30.3	24.0
Medicinal mineral oil [2]	24	100.0	1.5	0	17	8	10	77.1	66.7
Infested, untreated ears	25	100.0	1.5	14	0	20	0	0	0
Uninfested ears	25	0	0	0	0	0	0	------	100.0

[1] 1 larva was found in the husks of 1 ear of each of these series.
[2] Viscosity, S. U. at 100° F., 224 sec.

On examination of the ears on August 21, a total of 350 larvae were found in the 270 ears used, or an average of 1.3 per ear. Of these larvae 231 were alive; the survival, therefore, was at the rate of 42.8 percent, and at the time of examination 70.6 percent of the survivors were fifth or sixth instars. In the various treatments from 11.4 to 77.1 percent of the larvae had died, and from 3.8 to 66.7 percent of the treated ears were without live larvae. The results showed that the mineral oil had killed 20.4 percent more larvae and had protected 26.7 percent more ears than had peanut oil, which gave the best results among the 9 vegetable oils used. This was the earliest use of mineral oil for earworm control, and the results immediately suggested its superiority to vegetable oils for this purpose.

In March 1937, oils were applied to ears of Snowflake corn at Homestead, Fla., as soon as the silks had wilted, by use of a needle nozzle. In this case the tip of the nozzle was inserted for about 1 inch into the ears through the silk. Each kind of oil was applied to 25 ears, and a similar number of untreated ears were used as checks. The ears were attacked by larvae of *Laphygma frugiperda* as well as by those of *Heliothis armigera*, and at the time of roasting-ear harvest the larval population of treated and check ears combined consisted of 68.1 percent *Heliothis* and 31.9 percent *Laphygma*. The average number of living larvae in ears that received different treatments ranged from 0.4 to 1 per ear as compared with 2.4 per check ear, and the proportion of treated ears without living larvae ranged from 28 to 64 percent, as compared with none in the checks. The percentages of larvae that had been killed or had left the treated ears ranged from 58.3 to 83.3 as compared with the larval population of the checks. In these tests the mineral oil and the peanut oil gave almost identical results, and the tests indicated that these materials probably could be used in protecting corn ears against earworms.

During the summer of 1937, at New Haven, Conn., oils were applied to ears of sweet corn containing a comparatively light earworm infestation. The oils used and the methods of application are given in table 6. Whether applied with a needle nozzle, or by an oil can, or

TABLE 6.—*Results of applying oils to the tips of sweet-corn ears by 3 methods, for the control of the corn earworm, New Haven, Conn., 1937*

Method of application, date, and variety of corn used	Oil used	Ears treated or used as checks	Condition of ears at time of roasting-ear harvest: Containing living larvae	Condition of ears at time of roasting-ear harvest: Average larvae found per ear	Condition of ears at time of roasting-ear harvest: Ears protected [1]	Larvae destroyed [2]
		Number	*Percent*	*Number*	*Percent*	*Percent*
Needle nozzle,[3] Aug. 26, to Long Island Beauty	Peanut	25	20.0	0.2	54.5	64.3
	Castor	25	36.0	.4	18.2	21.4
	Corn	25	40.0	.4	9.1	21.4
	Soybean	25	56.0	.6	0	0
	Mineral [4]	24	16.7	.2	63.6	71.4
	Checks	24	45.8	.5		
Oil can,[5] Aug. 28, to Long Island Beauty	Castor	25	52.0	.6	0	0
	Corn	25	40.0	.5	9.1	14.3
	Soybean	25	36.0	.4	18.1	21.4
	Mineral [4]	25	8.0	.1	81.8	85.7
	Checks	24	45.8	.5		
Atomization,[6] Aug. 31, to Wipple's Yellow	Castor	25	8.0	.2	83.3	87.5
	Corn	25	12.0	.1	75.0	81.3
	Soybean	25	8.0	.1	83.3	87.5
	Tung	25	16.0	.2	66.7	75.0
	Mineral [4]	25	0	0	100.0	100.0
	Checks	25	48.0	.6		

[1] Difference in percent between the number of treated and check ears in which living larvae occurred.
[2] Difference in percent between the number of living larvae found in treated ears and in the checks.
[3] The needle nozzle was thrust through the silk at the tip of the ear for about 1 inch before the dosage was ejected.
[4] For a description of this oil see table 5, footnote 2.
[5] Ordinary oil cans were used in which ejection was obtained by pressing on the bottom. The tip of the spout was inserted about 1 inch into the silk at the tip of an ear, and about 1 ml. of oil was ejected.
[6] A paint spray gun was used, and the oil was applied to the exterior silks of ears. Air pressure was provided by an air compressor operated by a gasoline engine mounted on a wheelbarrow-type chassis.

atomized from a paint gun, the mineral oil gave results superior to those of any of the vegetable oils. The decidedly superior results obtained from atomization of the oils onto the exterior silks of ears is believed to be due to the fact that a much greater volume of oil can be discharged onto the ears by this method of application than by the needle nozzle or oil can methods.

Vegetable oils and the mineral oil were applied to series of sweet-corn ears in Dade County, Fla., in 1939, at a time when they bore fresh silks. Here again peanut oil proved to be more effective than other vegetable oils, and mineral oil proved to be superior to peanut oil.

VEGETABLE OILS USED WITH INSECTICIDES

Since vegetable oils used alone had shown some promise of usefulness in earworm control, various insecticides were used with them, usually as suspensions, and for comparison mineral oil alone was also used. The first series of these sprays studied was applied in August 1936 to artificially infested sweet-corn ears at New Haven, Conn. The method of procedure was the same as has been explained for the use of vegetable oils alone during the same period. The materials used, the methods of application, and the results are given in table 7. Further study of insecticides used with a vegetable oil was made in Homestead, Fla., during March 1937, when applications were made to ears of Snowflake corn in the field. Applications were made in the manner described for the use of oils alone at this location during the same period. The materials used and the results obtained are given in table 8. These materials were tested further in a field of Long Island Beauty sweet corn at New Haven, Conn., during the summer of 1937. The materials used, the methods of application, and the results obtained are given in table 9.

TABLE 7.—*Effect on the corn earworm of mixtures containing castor oil and insecticides injected into artificially infested sweet-corn ears by use of a needle nozzle, New Haven, Conn., 1936*

[Ears infested on Aug. 12; injections made on Aug. 18; ears examined on Aug. 24]

Insecticide used	Ears	Ears infested when examined	Average larvae found per ear	Larvae found in silks		Larvae found on kernels		Total dead	Ears without live larvae
				Alive	Dead	Alive	Dead		
	Number	*Percent*	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*	*Percent*
Phenothiazine [1]	24	79.2	1.2	0	18	1	11	96.7	95.8
Powdered pyrethrum [1]	23	73.9	1.1	3	19	3	8	81.8	78.3
Powdered derris root [1]	23	91.3	1.4	1	15	2	7	88.0	87.0
Powdered naphthalene [1]	25	88.0	1.3	2	18	5	7	78.1	72.0
Nicotine peat [1]	25	84.0	1.2	0	16	6	7	79.3	76.0
Nicotine sulfate [2]	22	90.9	1.4	4	19	0.	7	86.7	80.4
Castor oil alone [3]	26	92.3	1.3	5	4	26	0	11.4	3.8
Mineral oil alone [3]	21	100.0	1.5	0	17.	8	10	77.1	66.7
Untreated ears [3]	25	100.0	1.5	14	0	20	0	0	0

[1] This mixture consisted of 200 ml. of castor oil, 400 ml. of water, 10 gm. of insecticide, 1 gm. of sodium lauryl sulfate, and 5 gm. of sodium oleate.
[2] Spray mixture was similar to that described in footnote 1 except that 10 drops of 40-percent nicotine sulfate was used instead of 10 gm. of a dry insecticide.
[3] Data from table 5.

TABLE 8.—*Results of applying spray materials containing soybean oil and insecticides to ears of Snowflake roasting-ear corn by means of a needle nozzle thrust into the silk for about 1 inch before delivery of the dosage, Homestead, Fla., 1937*

[Sprays applied Mar. 17; ears examined Mar. 30; 25 ears used per treatment]

Insecticide used	Living larvae found in ears at time of harvest			Ears without living larvae	Larvae destroyed [1]
	Laphygma frugiperda	Heliothis armigera	Average live larvae per ear		
	Number	*Number*	*Number*	*Percent*	*Percent*
Phenothiazine [2]	1	9	0.4	64.0	83.3
Powdered pyrethrum [2]	7	7	.6	52.0	76.7
Powdered derris [2]	10	8	.7	36.0	70.0
Nicotine sulfate [2]	4	10	.6	60.0	76.7
Pyrethrins [2] [3]	8	1	.4	64.0	85.0
Hexachlorethane [2]	5	12	.7	44.0	71.7
Soybean oil alone	5	14	.8	36.0	68.3
Mineral oil alone [4]	2	10	.5	64.0	80.0
Untreated ears	19	41	2.4	0	----------

[1] Percentage fewer living larvae in the treated ears than in the checks.
[2] Mixtures consisted of 100 ml. of soybean oil, 200 ml. of water, 1 teaspoonful of insecticide, and 0.5 ml. of soap.
[3] A pyrethrum preparation consisting of 40 percent of petroleum extract of pyrethrum and 60 percent of diatomaceous earth.
[4] Description of this oil is given in table 5, footnote 2.

TABLE 9.—*Results of applying soybean oil containing insecticides to the tips of Long Island Beauty sweet-corn ears by two methods, New Haven, Conn., 1937*

[Ears treated Aug. 26; examined Sept. 7-8]

Method of application	Insecticide used (1 teaspoonful per 100 ml. oil, 1 ml. injected into each ear)	Ears treated	Condition of ears at time of roasting-ear harvest		Ears protected [1]	Larvae destroyed [2]
			With living larvae	Average larvae found per ear		
		Number	*Percent*	*Number*	*Percent*	*Percent*
Needle nozzle inserted 1 inch into silk mass	Phenothiazine	25	8.0	0.1	81.8	85.7
	Derris extract	25	12.0	.1	72.7	78.6
	Pyrethrins [3]	25	20.0	.2	54.5	64.3
	Nicotine sulfate	25	12.0	.1	72.7	78.6
	Hexachlorethane	25	12.0	.1	72.7	78.6
	Soybean oil alone	25	56.0	.6	0	0
	Mineral oil alone [4]	24	16.7	.2	63.6	71.4
	Untreated ears	24	45.8	.5		
Oil can with tip inserted 1 inch into silk mass	Phenothiazine	25	8.0	.1	81.8	85.7
	Derris extract	25	0	0	100.0	100.0
	Pyrethrins [3]	25	8.0	.1	81.8	85.7
	Nicotine sulfate	25	16.0	.2	63.6	71.4
	Hexachlorethane	25	16.0	.2	63.6	71.4
	Colloidal lead arsenate	25	12.0	1	72.7	78.6
	Soybean oil alone	25	36.0	.4	18.1	21.4
	Mineral oil alone [4]	25	8.0	.1	81.8	85.7
	Untreated ears	24	45.8	.5		

[1] Difference in percent between number of treated and check ears in which living larvae occurred.
[2] Difference in percent between the number of living larvae found in treated and in check ears.
[3] A pyrethrum preparation consisting of 40 percent petroleum extract of pyrethrum and 60 percent diatomaceous earth.
[4] Description is given in table 5, footnote 2.

Although the results given in tables 7 and 9 showed that vegetable oils containing insecticides were more effective in protecting corn ears than were the same oils when used alone, they were on the whole little if any better than mineral oil used alone. Most of the insecticides were objectionable in one way or another. Thus naphthalene caused rotting of the interior silk, while phenothiazine, powdered pyrethrum, powdered derris, nicotine peat, pyrethrum in diatomaceous earth, and hexachlorethane all left objectionable residues in the interior silks or on the kernels of treated ears. Colloidal lead arsenate had also been used for purposes of comparison but could not be used commercially. The general results indicated that from the standpoint of simplicity of handling, consistent effectiveness, availability, and freedom from residue that could be detected by appearance, odor or taste, mineral oil was much superior to any combination of vegetable oils with insecticides. A much more comprehensive evaluation of mineral oils, therefore, was begun.

MINERAL OILS USED ALONE

The very highly refined petroleum distillates known as white oils were available in commercial grades ranging in Saybolt viscosity from 50–350 seconds. These oils were colorless, odorless, tasteless, and of U. S. P. standard grade. Impurities that could not be filtered out had been burned out with fuming sulfuric acid. They could be used medicinally and in certain food preparations. There seemed to be no likelihood, therefore, that small quantities injected into the silk mass or that might spread onto the kernels, would be injurious to consumers of green corn.

Relation of Viscosity to Effectiveness

It was desirable at the outset to determine the comparative efficiency of mineral oils of different viscosities in protecting sweet-corn ears. In the first studies, oils ranging in viscosity from approximately 50–210 seconds, Saybolt, as listed in table 10, were obtained from two manufacturers, referred to as A and B. The oils were applied to replicated series of ears in a field of Golden Giant sweet corn grown in Dade County, Fla., during February and March 1938, when the silks had wilted and were beginning to turn brown. An ordinary oil can was used from which a dosage of approximately 1 ml. was injected into the silk mass of each ear by pressure on the bottom of the can. For purpose of comparison the medicinal mineral oil (224 seconds Saybolt) first studied, was also used. The results are given in table 10.

Table 10.—*Effectiveness of white oils applied to ears of Golden Giant sweet corn in protecting them against injury by earworms, Dade County, Fla., 1938*

[Ears having wilted silks were oiled Feb. 25–March 1, and were examined March 10–15]

Viscosity of oil (seconds)	Manufacturer	Replicates	Ears	Ears at time of harvest				Ears without live larvae	Ears with uninjured kernels
				Without live larvae		With live larvae			
				Kernels uninjured	Kernels injured	Kernels uninjured	Kernels injured		
		Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*	*Percent*
50–60	A	2	91	41	0	36	14	45.05	84.62
	B	3	75	41	0	27	7	54.67	90.67
	Total	5	166	82	0	63	21	49.40	87.35
65–75	A	2	80	52	0	24	4	65.00	95.00
	B	3	75	53	0	19	3	70.67	96.00
	Total	5	155	105	0	43	7	67.74	95.48
80–90	A	2	84	56	0	16	12	66.67	85.71
	A [1]	2	102	64	0	28	10	62.75	90.20
	B	3	75	60	0	10	5	80.00	93.33
	Total	7	261	180	0	54	27	68.97	89.65
95–105	A	2	114	69	0	36	14	61.06	87.61
125–135	A	2	110	85	0	21	4	77.27	96.36
	B	3	75	56	0	12	7	74.67	90.67
	Total	5	185	141	0	33	11	76.22	94.05
175–185	A	2	117	85	1	21	10	73.50	90.60
	B	3	75	57	0	10	8	76.00	89.33
	Total	5	192	142	1	31	18	74.48	90.10
200–210	A	2	108	79	0	18	11	73.15	89.81
224 (medicinal mineral oil)	A	2	94	69	0	17	8	73.40	91.49
Checks		18	181	0	0	23	158	0	12.71

[1] Oils of technical grade.

At the time of roasting-ear harvest from 45 … treated ears were free from infestation as co… check ears, and from 84.62 to 96.36 percent … the kernels as compared with only 12.71 p… The lighter oils seemed to be slightly the… effective. The percentages of larvae of differe… ears are given in table 11. The data in this… oils of lowest viscosity were least effective, … checks, 76.33 percent of the larval populatio… 50–60 seconds viscosity had been applied … migrated from the ears, whereas in ears trea… seconds viscosity, which was most effective larvae had been killed or had migrated. Control by the use of oils alone in these tests was better than usually was obtained in subsequent trials. The probable reason lay in the husk character of the ears, as hereinafter discussed.

TABLE 11.—*Occurrence of live earworms at roasting-ear harvest in ears of Golden Giant sweet corn to which white oils had been applied when silks were wilted, Dade County, Fla., 1938*

[Ears treated February 25–March 1; examined March 10–15]

Viscosity of oil (seconds)	Ears	Larvae found in silks in instar—[1]					
		2	3	4	5	6	Total
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
50–60	166	17.12	22.52	33.33	2.70	0	75.67
65–75	155	15.52	32.76	22.41	10.35	0	81.04
80–90	241	9.30	17.44	29.07	9.30	0	65.11
95–105	113	8.16	28.57	26.53	4.08	0	67.34
125–135	185	13.04	19.56	30.44	4.35	4.35	71.74
175–185	192	18.87	20.75	18.87	7.55	0	66.04
200–210	108	5.56	36.11	19.44	0	0	61.11
224 (medicinal mineral oil)	91	10.35	20.69	34.48	6.89	0	72.41
Checks	181	.19	5.26	24.37	11.90	.19	41.91

Viscosity of oil (seconds)	Larvae found in kernels in instar—[1]					Total larvae	Ears containing live larvae	Average larvae per ear	Reduction in larval populations[2]
	3	4	5	6	Total				
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
50–60	3.60	7.21	9.01	4.51	24.33	111	50.61	0.67	76.33
65–75	5.17	3.45	8.62	1.72	18.96	58	32.26	.37	86.93
80–90	2.33	8.14	10.47	13.95	34.89	86	31.03	.33	88.34
95–105	2.04	10.20	8.16	12.26	32.66	49	38.94	.43	84.81
125–135	2.17	10.87	6.52	8.70	28.26	46	23.78	.25	91.17
175–185	1.89	11.32	7.55	13.20	33.96	53	25.52	.28	90.11
200–210	2.78	13.89	8.33	13.89	38.89	36	26.85	.33	88.34
224 (medicinal mineral oil)	0	6.89	10.35	10.35	27.59	29	26.60	.31	89.05
Checks	1.56	14.82	33.33	8.38	58.09	513	100.00	2.83	----

[1] Percent of total number.

[2] By comparison with check.

These studies were continued in New Jersey during the summers of 1938 and 1939. White oils ranging in viscosity from approximately 125–345 seconds, obtained from two sources, were applied in 16 fields by use of a force oiler which delivered a uniform dosage of 0.75 ml. per ear, and the ears were treated at a time when the silks were wilted or had begun to turn brown. Five randomized replicates of 10 ears received a given treatment in each field. The results failed to show appreciable differences in the effectiveness of the different oils used, although the oil of 300–310 seconds viscosity seemed to be slightly less effective than the lighter oils in 1939. The results were variable in different fields and showed a range in effectiveness of all the oils in a field ranging from 36.8 to 85.89 percent of protected ears. The probable reason for the differences in effectiveness of the oiling in these trials may be found in the husk characteristics of the varieties used, as will be discussed in a subsequent section (p. 57).

General averages of the results obtained in all the fields during the summer of 1938 as given in table 12 show that the oils tested were practically identical in average effectiveness.

TABLE 12.—*Summary of results obtained by applying white oils of different viscosities and from different sources, to ears of 9 fields of corn for earworm control, New Jersey, 1938*

Viscosity of oil (seconds)	Oil obtained from source A		Oil obtained from source B		Ears examined	Ears in which the kernels were uninjured
	Ears examined	Injured ears	Ears examined	Injured ears		
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
125-135	249	73.09	200	52.00	449	63.70
200-210	250	66.20	200	57.00	450	63.78
250-260	248	68.14	200	52.00	448	60.94
300-310	245	69.80	200	55.50	445	63.37
335-345	249	71.89	200	54.00	449	63.92
All oils	1,241	70.43	1,000	54.10	2,241	63.14
Checks	249	20.18	200	7.00	449	14.25

DOSAGE PER EAR

It had been observed that when oil was applied to ears of corn by equipment that did not measure the dosage (the needle nozzle, ordinary oil cans, or paint spray gun), injury to the kernels, including rotting, sometimes occurred from the introduction of too much oil. It was desired to determine the least dosage that would be effective in protecting ears, without injuring them. In the summer of 1938, oil of 200-210 seconds viscosity obtained from source B was applied by a pipette of 1-cc. capacity, at dosages ranging from 0.2 to 1 ml. per ear in two fields of Golden Cross Bantam, when the silks were wilted or had begun to turn brown. In order to insure that the entire dosage would enter the ears, the pipette was thrust into the silk at the tip of an ear, and the dosage was applied slowly so that none would run outside. The dosages applied per ear and the results obtained are given in table 13. Except for the results of the 0.8-ml. dosage, the data indicate that dosages of 0.6 to 1 ml. per ear gave somewhat better control than did the smaller dosages. This finding was afterwards corroborated by further work with oil containing insecticides.

TABLE 13.—*Effectiveness of applications of mineral oil of 200-210 seconds viscosity to Golden Cross Bantam sweet corn in protecting the ears against injury by earworms; oil was applied by pipette, the tip of which was thrust about ½ inch into the silk at the tip of the ears; New Jersey, 1938*

Dosage of oil per ear (ml.)	Ears examined	Condition of ears at time of roasting-ear harvest		
		No live larvae present, kernels uninjured	Live larvae present, kernels uninjured	Total ears with uninjured kernels
	Number	*Percent*	*Percent*	*Percent*
0.2	100	39.0	22.0	61.0
0.4	100	40.0	22.0	62.0
0.6	100	50.0	15.0	65.0
0.8	100	43.0	14.0	57.0
1.0	100	48.0	16.0	64.0
All dosages	500	44.0	17.8	61.8
Checks	99	7.1	2.0	9.1

TABLE 14.—*Effectiveness of white oil of 200–210 seconds viscosity in protecting ears of different varieties of sweet corn from injury by earworms, when applied at the rate of 0.75 ml. per ear at a time when the silks had wilted or had begun to turn brown, New Jersey, summer of 1938*

Variety	Date examined	Oiled ears		Checks—untreated ears	
		Ears examined	Ears with uninjured kernels	Ears examined	Ears with uninjured kernels
		Number	*Percent*	*Number*	*Percent*
Early local white [1]	July 4	198	92.4	100	40.0
Evergreen	Aug. 30	50	84.0	25	10.0
Country Gentleman	do	50	80.0	25	16.0
Local white [1]	Aug. 19, 20	100	77.0	100	14.0
Big Yellow Dent	Aug. 21	100	67.0	100	5.0
Golden Cross Bantam	July 9–Sept. 10	250	57.2	249	18.1

[1] Unnamed local varieties of different season and characteristics.

EFFECTIVENESS OF OIL IN DIFFERENT VARIETIES OF CORN

During the summer of 1938 oil was applied to the ears of five varieties of sweet corn and one of field corn. The varieties treated and the results obtained are given in table 14. The difference in percentages of ears with kernels uninjured by the earworm, which ranged from 57.2 to 92.4 at time of roasting-ear harvest, seemed to be due to some character in which the ears of the several varieties differed from one another. This indicated that oil was not equally effective in ears of different types.

Since the type of husk was suspected of being the principal variable factor involved in the degree of effectiveness of different oils in protecting corn ears from earworm, seed of sweet-corn varieties having ears with unusually long and tight husks were obtained and planted at the East Glade Farm of the Florida Agricultural Experiment Station, Homestead, Fla., in the spring of 1939 for use in cooperative investigations of earworm control. In addition, four varieties of sweet corn and one variety of roasting-ear corn (Tuxpan), grown by farmers in nearby fields, were available for study. These varieties are listed in table 15. White oil of 200–210 seconds viscosity was applied to ears of the plots or fields mentioned, at a dosage of 0.75 ml. per ear, at a time when the silks were wilted or had begun to turn brown.

TABLE 15.—*Results of applying white oil of 200–210 seconds viscosity to ears of one variety of roasting-ear corn (Tuxpan) and 10 varieties of sweet corn at Homestead, Fla., March 1939*

Variety	Ears to which oil was applied					Checks—untreated ears					Reduction of larvae as compared with check
	Ears examined	Condition of ears		Ears in which live larvae were found		Ears examined	Condition of ears		Ears in which live larvae were found		
		Without live larvae	With uninjured kernels [1]	Larvae found	Average per ear		Without live larvae	With uninjured kernels [1]	Larvae found	Average per ear	
	Number	*Percent*	*Percent*	*Number*	*Number*	*Number*	*Percent*	*Percent*	*Number*	*Number*	*Percent*
Tuxpan [2]	250	27.60	90.40	176	0.70	50	4	40	103	2.06	66.0
Connecticut experimental variety [3]	243	88.07	93.42	20	.08	25	0	4	85	3.40	97.6
Kancross [3]	232	79.74	89.22	46	.19	25	0	0	90	3.60	94.7
Oregon Evergreen [3]	238	73.95	80.25	57	.19	25	0	12	57	2.28	91.7
Redgreen [3]	188	73.40	76.60	50	.26	25	0	0	65	2.60	90.0
Bantam Evergreen Hybrid [3]	75	66.67	76.00	28	.37	25	0	0	67	2.68	86.2
Stowell's Topcross [3]	95	65.26	75.79	31	.33	25	0	4	88	3.52	90.6
Senecross [3]	215	68.84	69.77	91	.42	25	0	0	99	3.96	89.4
Seneca Golden [2]	250	57.60	68.80	110	.44	25	0	0	98	3.92	88.8
Golden Cross Bantam [2]	250	44.80	64.80	159	.64	25	0	0	95	3.80	83.2
Senecross [2]	250	41.60	59.60	190	.76	25	0	0	104	4.16	81.7
Seneca 60 [2]	247	40.49	48.18	201	.81	25	0	0	73	2.92	72.3

[1] In addition to ears in which no living larvae were present, these lists include ears in which small larvae were present in the silk but had caused no injury to the kernels and would not do so by the time the ears were consumed as roasting ears.

[2] Varieties grown in commercial plantings on farms.

[3] These varieties were grown in plots at the East Glade Farm, Homestead, Fla., in cooperation with the Florida Agricultural Experiment Station.

The results of oil applications, given in table 15, were remarkably different in the different varieties, and the percentage of treated ears found to have uninjured kernels at time of roasting-ear harvest ranged from 90.40 for Tuxpan to 48.18 for Seneca 60. Although the silks of different varieties were exposed and the ears were oiled at different periods during about 2 weeks, from the middle to the last of February, they all were subjected to abundant and rather similar earworm populations. All the check ears were infested, and the average populations of live larvae in them at time of harvest ranged from 2.06 per ear for Tuxpan to 4.16 for Senecross.

In general the degree of control obtained by oiling these ears was found to vary directly with the length and tightness of the husks; and the varieties listed in table 15 fall roughly into a descending order of variation with respect to these characters. A study of the populations of living earworms, found in ears of the varieties mentioned, showed that there was a considerable reduction in numbers in the oiled ears at time of harvest as compared with the checks, the percentage reduction ranging from 97.6 in the Connecticut experimental variety to 66 in the Tuxpan. Except for the variety Tuxpan, which is grown extensively in Dade County, Fla., the varieties mentioned probably were grown in this region for the first time during 1939. Some varieties grew exceptionally well, whereas others did not seem to be adapted to this area. The order of listing (table 15) of varieties according to husk development and control obtained, therefore, does not indicate necessarily the character of growth or the rate of control likely to be obtained in the same varieties when grown in northern fields. These results led to further study of the husk character of sweet-corn ears, which is discussed subsequently.

Comparison of Methods of Application

A comparison of methods of applying vegetable oils and a medicinal mineral oil (table 6) had shown that a higher rate of earworm control resulted when the oils were atomized on the exterior silks than when applied to the tip of the ears by an ordinary oil can. It was considered desirable to study this subject in relation to mineral oils, but with the use of methods by which the dosages applied per ear could be measured, and to compare these with methods by which the amount of oil enter-

Table 16.—*Comparison of methods of applying white oil of 200–210 seconds viscosity to ears of Golden Cross Bantam sweet corn, Dade County, Fla., March 1939*

Method of application	Total ears[1]	Condition of ears at time of roasting-ear harvest		Average larvae found per ear
		Without live larvae	With uninjured kernels	
	Number	*Percent*	*Percent*	*Number*
Dropped on silk at tip of husk	100	51.0	56.0	0.51
Injected into tip of ears	100	55.0	58.0	.57
Atomized on external silks	100	51.0	61.0	.55
Sprayed on external silks	100	54.0	56.0	.49
All treated ears	400	52.8	57.8	.53
Checks, untreated ears	100	0	0	3.29

[1] 2 series of randomized plots were used in each of which 5 replicates of each treatment were made.

ing the ears could not be determined. Therefore white oil of 200–210 seconds viscosity was applied to ears of Golden Cross Bantam corn in Dade County, Fla., during March 1939, by the methods listed in table 16.

The results showed that whether the oil was dropped on the exterior silk at the ear tip, injected into the interior silk by a force oiler, or atomized or sprayed on the exterior silk, the resulting rates of control were similar, both in regard to the percentages of ears found to be with uninjured kernels and to the populations of living larvae found in the ears at time of harvest. However, when the oil was sprayed or atomized on the exterior silks a large part of it ran off the ear and was wasted, and several times as much oil was required to treat a given number of plants.

Since white oil is relatively expensive it proved to be most economical to obtain control by application of definite quantities of oil per ear made in such a way that little would be lost through run-off. Furthermore, considering the equipment required, the ears of a given acreage could be oiled by use of a force oiler by one man just as quickly as by the use of an atomizing equipment, which required two men to operate and which thus doubled the labor costs. Therefore, the atomizer method, which gave no better results than were obtained by use of force oilers, was abandoned for the most part, and in subsequent investigations force oilers usually were used.

TABLE 17.—*Degree of penetration of white oils colored with Sudan 3 stain into ears of Golden Cross Bantam sweet corn when applied at dosages of from 0.50–1.25 ml. per ear at a time when the silks were wilted; 5 ears received each treatment; Rancocas, N. J., 1939*

Viscosity of oil (seconds)	Distances of penetration of oil into ears when applied by pipette at dosages of—											
	0.50 ml.			0.75 ml.			1 ml.			1.25 ml.		
	Least	Greatest	Average	Least	Greatest	Average	Least	Greatest	Average	Least	Greatest	Average
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
50–55	4.9	9.1	6.9	4.6	10.5	7.8	6.8	8.8	7.6	-------	-------	-------
80–90	4.1	7.1	5.1	6.3	8.3	7.2	4.9	9.7	7.2	-------	-------	-------
125–135	3.7	4.8	4.2	4.3	6.8	5.3	6.5	9.9	7.5	-------	-------	-------
200–210	3.2	3.9	3.4	3.7	5.5	4.9	3.4	6.9	5.1	4.3	11.9	7.2
250–260	3.1	3.7	2.6	2.5	5.1	3.5	4.1	9.2	5.9	4.3	5.1	4.8
300–310	2.2	3.4	2.8	1.4	5.1	3.1	3.2	5.4	4.1	1.2	5.8	4.5
335–345	1.9	2.7	2.3	3.5	6.4	4.6	3.0	4.3	3.7	3.2	6.8	4.8
All oils			3.9		-------	5.2	-------	-------	5.9	-------	-------	-------

Viscosity of oil (seconds)	Average of all dosages	Proportion of ears in which oil reached lowest point of larval feeding when applied at rate of—					Ears in which oil reached the cobs
		0.50 ml.	0.75 ml.	1 ml.	1.25 ml.	All dosages	
	Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
50–55	7.4	100	100	100	-------	100	100
80–90	6.5	100	100	100	-------	100	100
125–135	5.7	100	100	100	-------	100	100
200–210	5.2	100	100	60	100	90	95
250–260	4.2	60	60	100	100	80	65
300–310	3.6	80	40	80	80	70	60
335–345	3.8	60	80	60	100	75	65
All oils	5.2	80	83	86	95	88	82

Degree of Penetration

In order to observe the penetration of white mineral oils of different viscosity in ears of sweet corn, oils ranging in viscosity from approximately 50–345 seconds were colored with Sudan 3 red stain and applied with a pipette at the rate of 0.50 to 1.25 ml., to ears of Golden Cross Bantam corn having wilted silks. The tip of the pipette was inserted slightly into the ear tip, and the dosage was released slowly so that all of it seeped into the ear. At time of roasting-ear harvest the locations to which the oils had penetrated into the ears could be determined by the red deposit left by the stain, particularly on the layer of husk leaves adjoining the kernels. Measurements of the distances from the tip of the husk to the lowest stained points in the ears showed that the degree of penetration varied with the viscosity of the oil, the average penetration for all dosages per oil ranging from 3.6 inches for an oil of 300–310 seconds viscosity to 7.4 inches for an oil of 50–55 seconds viscosity, as shown in table 17. Similarly, the average depth of penetration in inches for all oils ranged from 3.9 for a dosage of 0.50 ml. to 5.9 for a dosage of 1 ml.

The husks of treated ears were variable in length of extension beyond the tips of the cobs, both at the time when oils were applied and at the time of roasting-ear harvest when the ears were examined. Observations were made to determine whether the colored oil had reached the lowest point of earworm feeding, and it was found that the lighter oils had reached to these locations in all treated ears, but that the heavier oils had reached them in only about 75 percent of the ears (table 17).

Evidently the lighter oils penetrated too far into the ears, the heavier oils did not penetrate far enough, and the oils of 125–135 seconds and 200–210 seconds viscosity, gave the most desirable degree of penetration to reach the larvae where they were feeding at the time applications were made, without at the same time unnecessarily reaching the kernels.

Toxicity Tests

The dead larvae found in oiled ears were usually of the smaller instars, and not all the larvae that were in the ears at the time when oil was applied were killed. Migrants, especially those of larger instars, that entered the ears were not affected by the treatment. It was considered desirable, therefore, to determine in what way larvae were killed in the oiled ears. Larvae from the third to the sixth instars, inclusive, were collected from corn ears in the field and isolated in 2-ounce salve boxes, with sections of corn cobs bearing young kernels for food. A droplet of white oil of 200–210 seconds viscosity was applied to the dorsal surface of each larva by means of a small brush. The oil dispersed over the larva rather quickly, and 1 droplet covered the surface of a medium-sized larva. Only 1 of 85 larvae died during a 5-day period after treatment, all the others having fed and grown in size as usual during this time. White mineral oil is not, therefore, a contact insecticide, and when larvae die in treated ears it is not simply because the oil touches them but for some other reason.

By remaining in the interior silks rather than penetrating deeply into the ears, oils of 125–135 seconds and 200–210 seconds viscosity established a film about the silk strands, and, if the silk strands were pressed together rather tightly by the surrounding husks, the interior silks became saturated thoroughly with oil. The effect on the small earworms present in the interior silks at the time of application of oil was apparently the same as that obtained by dropping them into a vial of oil; that is, they were smothered by a covering of oil that cut off their air supply. Large larvae had eaten so much of the interior silk that they often were not shut off from access to air and therefore survived and continued to feed. Large larvae, such as fifth or sixth-instar migrants, apparently devoured sufficient silk to open a channel through which air could reach them as they went farther into the ears. Newly hatched larvae that sought to enter oiled ears apparently were unwilling to penetrate the oil-saturated silk or, if they ventured into a saturated portion, they were killed in the same way as were those present in the silks when oil was applied.

It has been pointed out previously that the proportion of sweet-corn ears protected by the oiling varies directly with the length and tightness of their husks. In ears with comparatively long, tight husks in which the oil saturates and remains suspended about the silk strands most perfectly, the oil not only killed the larvae in larger numbers by excluding the air that they needed (larger individuals in these ears were killed), but the saturated mass of silk served as a barrier against penetration by larvae to the kernels and often remained effective until the time of harvest. On the other hand, if the husks were short or loose and did not compress the silk strands sufficiently to cause the oil to remain suspended about them, the oil tended to run through the silk, the oil barrier was not established or was not lasting, fewer larvae were killed, and fewer ears were protected against injury. The toxicity tests and observations of treated ears in the field seem to show that earworms are killed in oiled ears by being smothered, and that the oil-saturated interior silk serves as a barrier through which the smaller larvae cannot penetrate to the kernels.

Ovicidal Value

To determine whether white oils would prevent hatching of earworm eggs, 8 oils ranging in viscosity from approximately 50–210 seconds, obtained from source A, together with the medicinal oil described in table 5, and 5 oils obtained from source B, which ranged in viscosity from about 50–185 seconds, were used. Earworm eggs, each attached to a strand of corn silk, were collected from ears in the field about 18 hours after they had been deposited by the moths. These were isolated in groups of 10, and a small droplet of a given oil was applied to the eggs of one group by a fine camel's-hair brush. In this way 140 eggs were treated with 14 different oils ranging in viscosity as described. Of these eggs 3, or 2.1 percent, hatched. Of two lots of untreated eggs, 19 out of 20, or 95 percent, hatched. These results indicate that white oils possess high ovicidal value against earworm eggs.

Effectiveness of Emulsions

To determine whether emulsions of mineral oil would be effective in protecting sweet-corn ears against earworms, mixtures were prepared containing mineral oil of 200–210 seconds viscosity in the proportions of from 1 to 8 parts of water. The oil was emulsified by use of triethenolamine and oleic acid, and was applied to series of ears of Golden Cross Bantam and Seneca 60 sweet corn, and to Tuxpan roasting-ear corn, when the silks were wilted (table 18). The proportion of uninjured ears in the series to which emulsions were applied was, on an average, 25.9 percent greater than in the checks, but the emulsions had protected 26.6 percent fewer ears than did applications of oil alone. In some instances, injury, including rotting, resulted from the introduction of water into the ears. From these results it appeared that emulsions of mineral oil would not be useful in affording protection to sweet-corn ears against injury by earworms.

TABLE 18.—*Effectiveness of mineral-oil emulsions applied at a dosage of 0.75 ml. per ear to 3 varieties of corn*[1] *in preventing injury by earworms, Dade County, Fla., 1939*

Proportion of oil and water	Ears examined	Ears with uninjured kernels at time of harvest
	Number	*Percent*
1:1	30	56.6
1:2	30	60.0
1:4	30	40.0
1:5	30	40.0
All emulsions	120	49.2
Oil alone	29	75.8
Untreated ears	30	23.3

[1] The varieties treated were Golden Cross Bantam and Seneca 60, in both of which no check ears were uninjured, and Tuxpan, of which 70 percent of the check ears were uninjured.

DISCUSSION

The investigations of white mineral oils used alone showed that these materials were useful in protecting sweet-corn ears against injury by earworms, but that under average conditions application of about 0.75 ml. per ear, made at a time when the silks were wilted, resulted in protection of only about 60 percent of the ears of commonly grown varieties. Although these results were promising and a high degree of control was obtained in ears having long, tight husks, further improvement was needed in the efficiency of the treatment on varieties having shorter and looser husks. It seemed probable that the effectiveness of the oil might be increased most readily by combining an insecticide with it.

MINERAL OIL USED WITH INSECTICIDES

During February and March 1939, in Dade County, Fla., a series of 67 oils, or oils containing insecticides in various combinations, were applied to ears in three fields of corn, of the varieties Tuxpan, Golden Cross Bantam, and Seneca 60. The principal materials used were the following:

Mineral oil alone (125–135, 200–210, 250–260, and 300–310 seconds viscosity).

Vegetable oil alone (peanut, corn, cottonseed, and soybean).

Derris extract (dissolved in cottonseed oil and combined with mineral oil in 7 combinations; extract in pine oil used with mineral oil; ground derris root (5 percent rotenone) used with mineral oil; and ground timbo root (5 percent rotenone) used with mineral oil).

Pyrethrum extract (20-percent extract, 2-percent extract in isopropyl alcohol, and 2-percent extract in acetone, all used with mineral oil in various proportions).

Insoluble insecticides ground in oil and used as suspensions (lead arsenate, phenothiazine, and cuprous cyanide).

Thiocyanates (2-(2-butoxyethoxy)ethyl ester of thiocyanic acid, and naphthyl isothiocyanate).

Contact insecticides (beta-naphthol and diphenyl).

Oil spreaders (phenoxyphenyl heptadecyl and diphenyl heptadecyl).

Combinations (white oils containing pyrethrins, rotenone, and cuprous cyanide in 12 combinations; white oil containing pyrethrins and cuprous cyanide in 4 combinations; and white oil containing rotenone and cuprous cyanide in 4 combinations.

The results of applying each of the 67 combinations to 10 ears in each of three fields were variable. Some of the materials injured the ears severely, most of them failed to increase the degree of protection against earworm injury above that obtained by use of oils alone, and it seems unnecessary, since most of the results were negative, to give even a brief summary of the large amount of data obtained. It was remarkable, however, that in every treatment in which pyrethrum extract was used with mineral oil the degree of protection afforded the ears was much higher than was obtained by use of any of the oils alone, or by any one of any combination of other materials in the oils.

Mineral Oil Containing Pyrethrins

The superiority of pyrethrins held true whether used alone with the oil or combined with other materials in oil. A generalized summary of the results in exploratory trials is given in table 19. Since the results of using pyrethrins in oil were so promising, this combination of materials was studied rather intensively during the summer of 1939 and during the ensuing periods of field investigation.

Table 19.—*Effectiveness of oil containing pyrethrins in protecting sweet-corn ears against injury by earworms as compared with oil containing all other materials studied during the spring of 1939, Dade County, Fla.*

Materials used	Plots	Ears examined	Live larvae found in the ears	Ears with uninjured kernels at time of harvest	Average live larvae per ear	Larval population destroyed [2]
	Number	*Number*	*Number*	*Percent*	*Number*	*Percent*
Mineral oil containing 1 percent of pyrethrins, alone or in combination with other materials	20	200	56	87.7	0.22	92.8
Mineral oil containing 0.1 percent of pyrethrins, alone or in combination with other materials	12	210	68	80.0	.32	89.3
Mineral oil containing any of all the other materials	142	1,707	1,165	70.3	.68	77.2
Untreated cars	6	205	611	11.4	2.98	....

[1] White oil of 200-210 seconds viscosity was used. The combinations were applied by pipette at a standard dosage of 0.5 ml. per ear at a time when the silks were wilted but had not turned brown. The varieties of corn used were Golden Cross Bantam and Seneca 60 sweet corn and Tuxpan roasting-ear corn. Examinations were made at roasting-ear harvest.

[2] Percentage fewer living larvae found in treated ears than in the checks.

EFFECT OF PYRETHRIN CONTENT

The exploratory trials were so promising that it seemed desirable to continue the evaluation of pyrethrins in oil to determine the most practical and effective percentages for commercial use. During the summer of 1939, therefore, mixtures were made with white oils ranging in viscosity from approximately 125–310 seconds, containing pyrethrins ranging from 0.1 to 1 percent, and applied to ears in seven fields of sweet corn at a uniform dosage of 0.75 ml. per ear, delivered by a force oiler at a time when the silks were wilted.

The results obtained with respect to pyrethrin content of the oils (table 20), both from the standpoint of percentages of ears found to

TABLE 20.—*Effectiveness in control of earworms of white oils containing from 0.1 to 1 percent of pyrethrins, applied to ears of sweet corn by a force oiler at the rate of 0.75 ml. per ear, New Jersey, summer of 1939*

Pyrethrins in oil[1] (percent)	Ears	Ears containing—					Larvae found in ears	Larvae found—				
		No larvae	Dead larvae only	Live and dead larvae	Live larvae only	No live larvae		In silks—		On kernels—		Total dead
								Live	Dead	Live	Dead	
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0.1	275	47.6	29.1	1.1	22.2	76.7	150	1.3	34.0	42.0	22.7	56.7
.2	199	43.7	40.2	2.5	13.6	83.9	127	2.4	35.4	22.8	39.4	74.8
.3	197	46.7	39.6	1.0	12.7	86.3	116	2.6	31.5	21.5	44.4	75.9
.4	200	45.5	40.5	2.5	11.5	86.0	121	.8	39.5	22.6	37.1	76.6
.5	276	42.4	44.2	2.5	10.9	86.6	174	.6	35.0	20.7	43.7	78.7
.6	199	44.7	49.3	1.5	4.5	94.0	130	.0	45.4	10.0	44.6	90.0
.7	199	42.2	50.8	2.0	5.0	93.0	130	.0	43.8	12.3	43.9	87.7
.8	200	49.0	43.0	.5	7.5	92.0	113	.0	32.7	14.2	53.1	85.8
.9	199	38.2	54.3	3.5	4.0	92.5	151	.0	43.0	9.3	47.7	90.7
1.0	277	41.2	50.5	1.4	6.9	91.7	188	1.1	39.9	11.1	47.9	87.8
Checks	561	6.4	0	0	93.6	6.4	728	7.3	0	92.7	0	0

[1] A 20-percent pyrethrum extract was used to prepare mixtures with oils of 125–135, 200–210, 250–260, and 300–310 seconds viscosity.

be without live larvae at time of harvest and percentages of the larval populations found dead in the treated ears, showed an important increase in effectiveness of oils containing 0.2 percent over oils containing 0.1 percent of pyrethrins. Effectiveness increased slightly up to a 0.6 percent pyrethrin content, but it was believed that the greater protection afforded the ears by increasing the pyrethrin content above 0.2 percent was not sufficient to warrant the additional cost involved. A pyrethrin content of 0.2 percent in oil was therefore selected as that which probably would prove to be most practical in commercial application of oil-pyrethrins to sweet-corn ears. The question of cost of materials is discussed in a later section.

EFFECTIVENESS IN OILS OF DIFFERENT VISCOSITY

Tests made in New Jersey during the summer of 1939, summarized in table 21, showed that, both from the standpoint of the percentages of ears found to be without live larvae at time of roasting-ear harvest and from the standpoint of the percentages of the larval populations found dead in the ears, no significant differences were apparent in the oils ranging in viscosity from approximately 125–260 seconds; but an oil of 300–310 seconds viscosity proved to be a less effective carrier of pyrethrins than lighter oils probably for the reason that it did not penetrate into the interior silk so efficiently as did the lighter oils.

Table 21.—*Effectiveness in control of earworms of applications of mineral oils of different viscosity, each containing from 0.1 to 1 percent pyrethrins, delivered by a force oiler, to ears in 7 fields of sweet corn at a dosage of 0.75 ml. per ear at a time when the silks were wilted, New Jersey, summer of 1939*

OILS CONTAINING FROM 0.1 TO 1 PERCENT PYRETHRINS

Viscosity of oil (seconds)	Ears	Ears containing—					Larvae found in ears	Larvae found				
		No larvae	Dead larvae only	Live and dead larvae	Live larvae only	No live larvae		In silks		On kernels		Total dead
								Live	Dead	Live	Dead	
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
125-135	558	41.3	47.8	1.6	9.3	89.1	366	0.3	38.0	16.1	45.6	83.6
200-210	551	42.8	47.5	1.8	7.9	90.3	369	.3	37.7	14.9	47.1	84.8
250-260	559	47.7	41.5	1.6	9.2	89.2	318	.6	42.5	18.6	38.3	80.8
300-310	553	44.7	38.5	2.4	14.4	83.2	350	2.3	36.0	25.1	36.6	72.6
All oils	2,221	44.1	43.8	1.9	10.2	87.9	1,403	.9	38.4	18.6	42.1	80.5

OILS ALONE

Viscosity of oil (seconds)	Ears	No larvae	Dead larvae only	Live and dead larvae	Live larvae only	No live larvae	Larvae found in ears	In silks: Live	In silks: Dead	On kernels: Live	On kernels: Dead	Total dead
125-135	70	41.4	18.6	0	40.0	60.0	46	0	26.1	67.4	6.5	32.6
200-210	70	38.6	21.4	0	40.0	60.0	47	6.3	12.8	59.6	21.3	34.1
250-260	70	41.4	15.7	0	42.9	57.1	44	0	13.6	75.0	11.4	25.0
300-310	70	38.6	15.7	1.4	44.3	54.3	46	0	19.6	73.9	6.5	26.1
All oils	280	40.0	17.8	.4	41.8	57.8	183	1.7	18.0	68.8	11.5	29.5
Checks	564	6.4	0	0	93.6	6.4	728	7.3	0	92.7	0	0

EFFECTIVENESS IN DIFFERENT VARIETIES OF CORN

As when oils alone were used, the effectiveness of oil containing pyrethrins varied in different varieties of corn and in the same variety grown under different environmental conditions. This was due principally to the fact that the husk character of ears varied in different varieties and under different weather conditions. In ears of Tuxpan, a variety having tight husks, larvae penetrated slowly, and even at time of harvest had failed to reach the kernels of 45 percent of the check ears; whereas in Golden Cross Bantam, with comparatively loose husks, larvae had reached the kernels in all check ears. In the ears to which oil containing 0.1 percent of pyrethrins was applied, 72 percent of Golden Cross Bantam and 100 percent of Tuxpan had uninjured kernels at time of harvest. In Golden Cross Bantam ears the reduction of living larvae, as compared with populations in check ears at time of roasting-ear harvest, was 92 percent with 1 percent of pyrethrins and 89.9 percent with 0.1 percent of pyrethrins, as compared with the reduction in Tuxpan of 89.5 percent with 1 percent of pyrethrins and 85.0 percent with 0.1 percent of pyrethrins.

In the summer of 1939 applications of white oils containing from 0.1 to 1 percent of pyrethrins gave variable results in ears of different varieties of sweet corn, as shown in table 22, but the treatments were most effective in a variety of local, white sweet corn having relatively long, tight husks and were least effective in ears of Golden Cross Bantam affected adversely by environmental conditions.

TABLE 22.—*Effectiveness of applying white oils containing from 0.1 to 1 percent pyrethrins to ears of 7 fields of sweet corn, delivered by a force oiler, at the rate of 0.75 ml. per ear, in affording protection against earworm injury, New Jersey, summer of 1939*

Variety	Dates—		Ears	Ears containing—					Larvae found in ears	Larvae found—				
	Treated	Examined		No larvae	Dead larvae only	Live and dead larvae	Live larvae only	No live larvae		In silks		On kernels		Total dead
										Live	Dead	Live	Dead	
			Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Marcross	June 25	July 4	391	68.8	22.7	1.3	7.2	91.5	127	4.7	26.0	21.3	48.0	74.0
Marcross	June 28	July 6	115	40.9	42.6	.9	15.6	83.5	71	0	50.7	26.7	22.5	73.2
Local early white	June 27	July 5	117	60.7	23.9	3.4	12.0	84.6	50	0	22.0	36.0	42.0	64.0
Golden Cross Bantam	Aug. 2-3	Aug. 10-11	400	41.7	38.5	2.3	17.5	80.2	266	0	15.4	30.5	54.1	69.5
Golden Cross Bantam	Aug. 21-22	Aug. 28-29	400	24.5	63.7	2.3	9.5	88.2	301	.8	40.2	13.0	46.0	86.2
Local white	Aug. 22-23	Sept. 1-2	400	45.5	46.0	1.5	7.0	91.5	245	.8	62.8	13.1	23.3	86.1
Local white	Aug. 23-25	do	398	36.4	54.0	1.8	7.8	90.4	283	.3	42.1	13.1	44.5	86.6
Check, all fields			564	6.4	0	0	93.6	6.4	728	7.3	0	92.7	0	0

Other trials with sweet corn and one type of field corn also showed variations in effectiveness, but these differences were due principally to differences in length and tightness of the husks, as mentioned in the section on use of oils alone. This subject is discussed in greater detail in a subsequent section.

MORTALITY OF LARVAE IN TREATED EARS

The percentages of larvae found dead in sweet-corn ears at time of roasting-ear harvest, after the application of oil-pyrethrum when the silks were wilted, served as a measurement of effectiveness of the insecticide.

In the work with white oils alone it had been found that a dosage of 0.75 ml. per ear was most satisfactory for general use in sweet corn. To determine whether this dosage would be satisfactory for oil-pyrethrum, a series of seven white oils ranging in viscosity from approximately 50–345 seconds, each containing 0.1 percent of pyrethrins, were applied at different dosages to ears of Golden Cross Bantam sweet corn at a time when the silks were wilted. The results

TABLE 23.—*Mortality of earworms in ears of Golden Cross Bantam sweet corn to which white oils of various viscosities containing 0.1 percent pyrethrins had been applied at various dosages, Rancocas, N. J., 1939*

[Oil applied Sept. 11; ears examined Sept. 17]

Viscosity of oil base (seconds)	Dosage of oil per ear	Ears examined	Larvae found in the ears		Viscosity of oil base (seconds)	Dosage of oil per ear	Ears examined	Larvae found in the ears	
			Total	Dead				Total	Dead
	Ml.	*Number*	*Number*	*Percent*		*Ml.*	*Number*	*Number*	*Percent*
50-345	0.50	35	70	62.86	125-135	1.00	15	36	77.8
50-345	.75	35	76	75.00	200-210	.50	20	45	77.8
50-345	1.00	35	78	80.77	250-260	.75	20	44	72.7
50-345	1.25	20	52	82.69	300-310	1.00	20	38	63.2
Checks		10	18	0	335-345	1.25	20	31	38.7
50-55	.50	15	37	89.2	Checks	---	10	18	0
80-90	.75	15	45	95.6					

given in table 23 show that the percentage of larvae found dead in ears to which 0.75 ml. of oil-pyrethrum had been applied was almost as high or higher than was obtained when larger amounts of the mixture were used per ear, but that a dosage of 0.50 ml. gave smaller mortality. Considering the cost of oil-pyrethrum and the possibility of injury to the ears resulting from the introduction of too great a dosage of oil, the dosage rate of 0.75 ml. seemed also to be most suitable for oil-pyrethrins.

Table 23 also indicates that the highest mortality of larvae followed use of pyrethrins in the lighter oils and that a lesser number of larvae died following the use of the heavier oils containing pyrethrins. The lighter oils penetrated more deeply into the ears and the chances of their reaching an increased proportion of the larvae were greater than was the case with the heavier oils.

The relation between the pyrethrin content of the oil and its insecticidal effectiveness has already been discussed, and data on this relationship are to be found in table 20.

TOXICITY TESTS

It has already been shown (p. 30) that white oils alone are not effective as contact insecticides. Tests against individual larvae were therefore made to determine whether the addition of pyrethrins would make white oils effective as contact insecticides. In most of these tests larvae collected from corn ears in the field were isolated in 2-ounce tin salve boxes in each of which a section of corn cob bearing tender kernels was placed as food, and a small droplet of the material to be tested was applied to the dorsal surface of each earworm by use of a small camel's-hair brush. In most cases the salve boxes were unventilated. The results obtained with a white oil of 125–135 seconds viscosity, containing pyrethrins, are shown in table 24.

TABLE 24.—*Effectiveness of white oil of 125–135 seconds viscosity containing pyrethrins as a contact insecticide against earworms when a small droplet was applied per larvae, summer of 1939*

Pyrethrin content (percent)	Stage of growth of larvae treated: Fifth instar, Medium	Fifth instar, Premolt	Sixth instar, New	Sixth instar, Large	Total larvae	Mortality
	Number	*Number*	*Number*	*Number*	*Number*	*Percent*
0.1	2	12	4	8	26	92.3
0.09	2	4	2	2	10	100.0
0.08	1	5	2	2	10	100.0
0.07	4	2	2	2	10	100.0
0.06	4	2	2	2	10	100.0
0.05	6	15	13	14	48	93.8
0.04	4	7	4	7	22	81.8
0.03	5	6	4	7	22	77.3
0.02	5	6	4	7	22	63.6
0.01	6	5	4	7	22	18.2
Checks		5		31	36	2.8

In an additional series of treatments in unventilated boxes, 0.75 ml. of oil of 125–135 seconds viscosity containing 0.2 percent of pyrethrins, was injected into small balls of absorbent paper which were then wrapped in cotton and one so placed in each cage that the larva could not come in contact with the insecticide. All the 10 larvae subjected to this treatment survived, indicating that oil-pyrethrins is not effective as a fumigant. Oil containing from 0.1 to 0.05 percent of pyrethrins was highly effective as a contact insecticide, but the effectiveness rapidly decreased when smaller concentrations of pyrethrins were used.

Studies of the effectiveness of white oils ranging in viscosity from approximately 125–310 seconds, and containing 0.1, 0.5, or 1 percent of pyrethrins as contact insecticides, indicated that the heavier oils containing the lowest percentages of pyrethrins were least effective. In further tests in which 0.05 or 0.1 percent of pyrethrins was used in white oils, oil of 50–55 seconds viscosity caused 91.8 percent mortality of 49 treated larvae; oil of 125–135 seconds viscosity caused 96.3 percent mortality of 54 larvae; and oil of 200–210 seconds viscosity caused 91.4 percent mortality of 58 larvae. The results of all tests seemed to show that white oils ranging in viscosity from approximately 50–210 seconds, containing at least 0.05 percent of pyrethrins, were equally effective as contact insecticides against earworms.

RAPIDITY OF KILL

Study showed that the rapidity of kill of earworms by oil containing pyrethrins is proportionate to the amount of the insecticide with which they are wetted. In ears to which 0.75 ml. or more of oil containing 0.2 percent of pyrethrins was applied, the larvae present in the interior silk near the tip of the husk, which were thoroughly wetted by, or practically immersed in, the insecticide, died almost instantly, especially if they were the smaller instars. Larvae that had penetrated for greater distances into the ears died more slowly, but in any case larvae that the insecticide reached did not feed afterward. In the toxicity tests previously described, the larvae became very active soon after the insecticide was deposited on them. They became paralyzed, however, within 2 or 3 minutes, lying characteristically on their backs, although they might be capable of feeble movements for some minutes. In the treated ears some larvae, particularly fifth or sixth instars, crawled rapidly from the ears, but these usually became paralyzed by the time they reached the exterior silk and either died there or fell to the ground. Larvae that were found alive in the ears at harvesttime usually were those so located at the time of application that the insecticide did not reach them. This was particularly the case with larvae that reached the kernels several inches below the tip of the cob before treatment, and more especially in ears having short or loose husks into which the larvae could penetrate rapidly.

TABLE 25.—*Effectiveness of white oil of 125–135 seconds viscosity containing 0.2 percent of pyrethrins and an activator or an oil spreading agent, in affording protection from earworms to ears of sweet or roasting-ear corn, when applied at a dosage of 0.75 ml., Florida, 1941*

Oil and added materials	Additional agent	Protection afforded to ears when applied to— Tuxpan roasting-ear corn: Ears treated	Tuxpan: Ears without live larvae	Tuxpan: Ears with uninjured kernels	Golden Cross Bantam sweet corn: Ears treated	Golden Cross Bantam: Ears without live larvae	Golden Cross Bantam: Ears with uninjured kernels
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*
Extract "odorless" of 1941	2	73	97.3	98.6	73	83.6	84.9
Extract of 1940	20	73	94.5	93.2	75	72.0	65.3
Extract plus 2 percent activator A	2	71	92.9	95.8	75	93.3	82.7
Extract plus 0.5 percent spreader A	2	25	88.0	96.0	50	76.0	74.0
Commercial oil-pyrethrum C[1]		98	90.8	91.9	75	92.0	82.7
Dichloroethyl ether in oil	2	100	89.0	92.0	75	77.3	74.7
Checks—untreated ears		100	0	42.0	75	17.3	28.0
Butyl stearate	2	25	88.0	92.0	25	80.0	80.0
Dichlorostearic acid	2	25	92.0	92.0	25	84.0	84.0
Ethylxylyl stearate	2	25	88.0	92.0	25	96.0	96.0
Methyl dichlorostearate	2	25	92.0	92.0	25	86.0	82.0
Phenoxyphenyl stearic acid	2	25	84.0	92.0	25	88.0	80.0
Tetrahydro-naphthyl-stearic acid	2	25	92.0	96.0	24	87.5	87.5
Butyl oleate	2	25	100.0	100.0	23	95.6	91.3
Oil-pyrethrins alone	2	25	88.0	96.0	25	96.6	96.0
Checks		25	0	42.0	25	28.0	32.0

[1] A commercial preparation.

PYRETHRUM ACTIVATORS AND OIL SPREADERS

In an effort to increase the protection afforded sweet-corn ears by the application of oil-pyrethrins, attention was given to so-called pyrethrum activators and oil spreaders. The results of adding an activator or a spreading agent to oil-pyrethrum, as compared with home-mixed and commercial oil-pyrethrum preparations without such additions, are given in table 25.

The results showed that these materials did not add to the effectiveness of oil-pyrethrum, with the possible exception of butyl oleate. Further tests, however, failed to confirm the usefulness even of this material; it may be said therefore that none of the materials tested so far have proved to be useful in increasing the effectiveness of oil-pyrethrum appreciably in protecting sweet-corn ears against injury by earworms. Apparently pyrethrum extract procured in 1940 had become somewhat less potent by 1941.

COMMERCIAL OIL-PYRETHRUM MIXTURES

During 1940 at least one, and during 1941 several, oil-pyrethrum mixtures prepared especially for control of earworms in sweet corn were offered on the general market. Three of these commercial mixtures were compared with home-mixed preparations when applied to the ears of several fields of sweet corn in New Jersey during the summer of 1941. The results, given in table 26, indicated that two of the commercial preparations were equal and that one was uniformly superior to home-mixed oil-pyrethrum in protecting sweet-corn ears against earworms. The latter commercial preparation was found to contain somewhat more than the recommended 0.2-percent concentration of pyrethrins, which probably explains its greater effectiveness.

TABLE 26.—*Effectiveness of commercial preparations of white oil containing 0.2 percent pyrethrins in affording protection against earworms to ears of sweet corn, when applied at a dosage of 0.75 ml. per ear, New Jersey, 1941*

Material used	Ears examined	Ears found at time of roasting-ear harvest—				Ears without live larvae	Ears with uninjured kernels
		Without live larvae		With live larvae			
		Kernels uninjured	Kernels injured	Kernels uninjured	Kernels injured		
	Number	*Number*	*Number*	*Number*	*Number*	*Percent*	*Percent*
Home-mixed; 2-percent extract used	[1] 120	75	21	5	19	80.00	66.67
Above mixture plus 2 percent butyl oleate	[2] 100	66	16	7	11	82.00	73.00
Commercial mixture A	[2] 96	76	12	6	2	91.67	85.42
Commercial mixture B	[2] 97	61	17	7	12	80.41	70.10
Commercial mixture C	[3] 320	218	40	14	48	80.62	72.50
Oil containing 2-percent dichloroethyl ether	[4] 266	170	40	16	40	78.95	69.92
Checks—untreated ears	[3] 370	15	2	30	323	4.59	12.16

[1] 4 fields of Golden Cross Bantam and 1 field of local, white sweet corn were used.
[2] 3 fields of Golden Cross Bantam and 1 field of local, white sweet corn were used.
[3] 12 lots of ears were examined in 5 fields each of Golden Cross Bantam and local, white sweet corn.
[4] 9 lots of ears were examined in 4 fields of Golden Cross Bantam and four fields of local, white sweet corn.

REPELLENT EFFECT OF OIL-PYRETHRINS

Evidence has accumulated to show that earworms do not find the interior silk of sweet corn to which oil-pyrethrins has been applied attractive as food, and that they are repelled by it. In the fields where experimental applications were made, larvae often migrated to the treated ears and sought to enter them through the silk at the tip of the husk. They seldom penetrated into the interior silk or to the kernels but frequently were found in the silk just within the husk at the tip where the least amount of oil had remained or where none at all was found if the dosage had been applied about one-half inch into the interior silk. Occasionally larvae bored through the husk to reach the parts of the ears specially attractive as food. If they reached the oil-impregnated silk of treated ears they often discontinued feeding and migrated elsewhere to try again. In controlled experiments, larvae were observed to burrow into the ears in this way repeatedly, and each time they reached the silk to which oil-pyrethrum had been applied they discontinued feeding and began to bore in a different location. Although not all larvae seem to be repelled, the evidence seems to show that oil-pyrethrum is a repellent, as well as a contact insecticide, to most larvae and that the full measure of its value cannot be determined only by records of the percentages of larvae actually killed within treated ears.

DISCUSSION OF OIL-PYRETHRINS

Data have been presented in the preceding sections to show that oil-pyrethrins properly used is a powerful contact insecticide which, without materially injuring any part of sweet-corn ears, without leaving discernible residues, and without imparting objectionable odor or flavor to the kernels, is highly effective under usual field conditions in protecting against injury by earworms. Under average field conditions, when all or nearly all the untreated ears become infested with from 1 to 10 larvae per ear, the oil-pyrethrins seems to protect completely about 75 percent of the ears. In less severe infestations in sweet corn not adversely affected by environmental conditions, the average degree of freedom from injury is increasingly greater. When earworms are very abundant, and particularly when the ears have been adversely affected by environmental conditions, a lower degree of control is obtained; hence, although mineral oil to which pyrethrins have been added is more effective than mineral oil alone, and although oil-pyrethrins probably is more satisfactory in general than any other previously known agent for protecting sweet-corn ears against injury by earworms, there are several factors that limit its usefulness. These factors, including the interference of oiling with pollination of the ears, and the cost of pyrethrum, are discussed in later sections.

Mineral Oil Containing Dichloroethyl Ether

In view of the cost of pyrethrum, substitutes were sought which would give a higher rate of protection to the ears or would be less expensive. To this end 115 materials, combinations of materials, or materials used in different concentrations in mineral oil, were studied during the summer of 1939. These included, besides white oils of various viscosities, selections of less highly refined mineral oils, including lubricating oils, and, besides pyrethrum, several thiocyanates, diphenylamine, dichloroethyl ether, and hexachlorethane. Of the mixtures tested, those consisting of dichloroethyl ether in white oil seemed to be promising, as shown in the summary of results obtained in the exploratory tests given in table 27. Since the degree of protection to ears resulting from applications of oil-dichloroethyl ether in these tests was at least equal to that obtained through applications of oil-pyrethrins, and since it was much less expensive than pyrethrum, this material was studied rather intensively during subsequent periods of field work.

TABLE 27.—*Effectiveness of mineral oils* [1] *containing pyrethrins* [2], *dichloroethyl ether* [3], *or other materials in protecting sweet-corn ears against injury by earworms, when applied at the rate of 0.75 ml. per ear, New Jersey, summer of 1939*

Materials used	Lots of materials	Total ears	Ears without living larvae at time of harvest	Total larvae found in ears	Larvae found dead
	Number	*Number*	*Percent*	*Number*	*Percent*
Oils used alone	10	400	55.2	278	32.4
Oils containing 0.1 percent or more pyrethrins	29	1,036	81.5	698	70.5
Oils containing 1 percent or more dichloroethyl ether	14	359	81.6	278	73.4
Oils containing one or more other materials	18	674	62.2	472	40.3
Untreated ears		400	2.5	557	0

[1] Includes other than white oils, such as lubricating oils.
[2] Does not include 44 materials used to study the effectiveness of from 0.1 to 1 percent of pyrethrins in oil.
[3] Includes exploratory trials of oils containing dichloroethyl ether.

EFFECTIVENESS IN RELATION TO DICHLOROETHYL ETHER CONTENT

In the preliminary investigations during the summer of 1939, dichloroethyl ether was used in white oil of 125–135 and 200–210 seconds viscosity in concentrations ranging from 0.1 to 10 percent by volume. It was used alone in the oils or in addition to pyrethrins. A summary of the results obtained is given in table 28. Oil containing 5 percent or more of dichloroethyl ether burned the husks and rotted the silks of sweet-corn ears to which it was applied. In the 10 experiments in which dichloroethyl ether was used alone in oil, as compared with similar concentrations of oil-dichloroethyl ether containing pyrethrins, the latter combination gave superior protection in half the instances. The fact that the higher concentrations of dichloroethyl ether caused injury to the ears and that the lower concentrations gave too low a degree of control indicated that the most effective concentrations would probably be found between 0.5 and 5 percent in oil.

In a further series of tests during the summer of 1939, oil of 200–210 seconds viscosity containing from 1 to 5 percent of dichloroethyl ether was applied to ears in three fields of sweet corn. The results, summarized in table 29, indicate that there was a regular increase in effectiveness as the dichloroethyl ether content was increased to 3 percent. The use of 5 percent dichloroethyl ether in oil caused serious burning of the husks, the use of 4 percent caused occasional burning, 3 percent caused burning in rare instances, and lesser concentrations caused no injury. Therefore further studies were limited to oil containing from 1 to 3 percent of dichloroethyl ether.

In Florida, in the spring of 1940, oils of 125–135 and 200–210 seconds viscosity containing from 1 to 3 percent of dichloroethyl ether were applied to the ears in replicate plots of Golden Cross Bantam and Truckers' Favorite corn. The results of these tests are summarized in table 30.

TABLE 28.—*Effectiveness of dichloroethyl ether, alone or in combination with pyrethrins, in white oils in affording protection to sweet corn against earworms when applied at a dosage of 0.75 ml. per ear, New Jersey, summer of 1939*

Viscosity of oil used (seconds)	Fields [1]	Ears [1]	Dichloroethyl ether alone in oil: Dichloroethyl ether content	Dichloroethyl ether alone in oil: Ears without live larvae	Dichloroethyl ether alone in oil: Larvae found dead	Dichloroethyl ether plus pyrethrins: Dichloroethyl ether content	Dichloroethyl ether plus pyrethrins: Pyrethrin content	Dichloroethyl ether plus pyrethrins: Ears without live larvae	Dichloroethyl ether plus pyrethrins: Larvae found dead
	Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
125-135	1	10	[2] 10.0	60.0	71.4	[2] 10.0	0.1	100.0	100.0
	1	10	[2] 5.0	90.0	88.9	[2] 5.0	.1	90.0	83.3
	4	40	1.0	82.5	74.2	1.0	.1	70.0	65.7
	3	30	.5	93.3	91.3	.5	.1	86.2	75.0
	3	30	.1	75.9	68.2	.2	.01	60.0	40.0
200-210	1	10	[2] 10.0	80.0	60.0	[2] 10.0	.1	90.0	80.0
	1	10	[2] 5.0	90.0	85.7	[2] 5.0	.1	100.0	100.0
	4	40	1.0	82.5	75.0	1.0	.1	82.5	81.1
	3	30	.5	70.0	62.5	.5	.05	90.0	85.0
	3	30	------	------	------	.1	.01	86.0	84.4
	3	30	.1	66.7	52.0	.5	.05	73.3	64.0
	3	30	------	------	------	.1	.01	80.0	52.9
Checks	4	400	------	2.5	0	------	------	------	------

[1] Number of fields and number of ears is applicable to each series of tests.
[2] These concentrations caused burning of the husks and rotting of the interior silks.

TABLE 29.—*Effectiveness against earworm injury of applications of white oil of 200–210 seconds viscosity containing from 1 to 5 percent of dichloroethyl ether, to ears of sweet corn at the rate of 0.75 ml. per ear, New Jersey, summer of 1939*

Dichloroethyl ether in oil (percent)	Ears	Ears containing—: No larvae	Ears containing—: Dead larvae only	Ears containing—: Live and dead larvae	Ears containing—: Live larvae only	Ears containing—: No live larvae	Larvae found in the ears	Larvae found—: In silks: Live	Larvae found—: In silks: Dead	Larvae found—: On kernels: Live	Larvae found—: On kernels: Dead	Larvae found—: Larvae found dead
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	598	12.4	69.1	11.0	7.5	81.5	765	2.7	62.5	11.8	23.0	85.5
2	298	10.1	78.5	6.0	5.4	88.6	384	2.1	57.5	7.3	33.1	90.6
3	249	15.3	79.5	2.8	2.4	94.8	292	1.0	66.1	3.4	29.5	95.6
4	248	9.3	81.5	5.2	4.0	90.8	344	.6	68.6	6.1	24.7	93.3
5	250	6.0	86.0	4.8	3.2	92.0	364	.8	70.9	4.7	23.6	94.5
0.1 percent pyrethrins	293	22.9	58.6	8.9	11.6	79.5	282	2.1	59.6	91.0	18.4	78.0
Untreated ears	150	0	0	0	100.0	0	[1] 271	14.0	0	86.0	0	0

[1] In the check ears 60.5 percent of the larvae were those of *Heliothis armigera* and 39.5 percent were those of *Laphygma frugiperda*. The identity of all the larvae in the treated ears was not assured because many of them that had died were decayed, or were discolored.

The average percentages of ears found with uninjured kernels at time of roasting-ear harvest were as follows: For 1 percent dichloroethyl ether content in oil, 45.9 percent; for 1½ percent in oil, 58.5 percent; for 2 percent in oil, 62.1 percent; for 2½ percent in oil, 64.7 percent; and for 3 percent in oil, 65.8 percent. For all percentages of dichloroethyl ether in oils studied 59.4 percent of 1,422 treated ears were protected, and in the checks 9.1 percent of 297 ears were uninjured. All the fields were injured by drought, and the conditions were unfavorable for obtaining protection of a high percentage of ears by oiling. Nevertheless, the increases in percentages of ears with uninjured kernels as between the checks and ears to which 1, 1½, 2, 2½, and 3 percent of dichloroethyl ether in oil were applied were 36.8, 49.4, 53.0, 55.6, and 56.7, respectively. The degree of protection afforded the ears increased considerably as the proportion of dichloroethyl ether used in the oils was increased from 1 percent to 2 percent, but at concentrations greater than 2 percent in oil the increase in degree of protection to the ears was less pronounced.

TABLE 30.—*Effectiveness of white oils of 125–135 or 200–210 viscosity containing from 1 to 3 percent of dichloroethyl ether in protecting corn from earworms, the mixtures being applied at the dosage of 0.75 ml. per ear and 2 tests being made with pyrethrum for comparison*

Dichloroethyl ether content in oil	Ears	Ears found at time of harvest—				Ears with uninjured kernels
		Without live larvae		With live larvae		
		Kernels uninjured	Kernels injured	Kernels uninjured	Kernels injured	
Percent	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*
GOLDEN CROSS BANTAM, SANFORD, FLA., 1940. TREATED MAY 31 TO JUNE 1; EXAMINED JUNE 8 TO 10						
1	240	81	41	21	91	42.5
1½	232	96	25	30	81	54.3
2	230	94	24	38	74	57.4
2½	233	94	24	50	65	61.8
3	237	92	33	59	53	63.7
Checks	217	21	0	1	222	10.1
TRUCKERS' FAVORITE, OCALA, FLA., 1940. TREATED JUNE 13; EXAMINED JUNE 20						
1	50	23	8	8	11	62.0
1½	50	31	4	8	7	78.0
2	50	32	5	10	3	84.0
2½	50	29	3	10	8	78.0
3	50	26	6	12	6	76.0
Checks	50	2	0	0	48	4.0
NINE FIELDS OF SWEET CORN AND ONE OF YELLOW DENT IN NEW JERSEY, 1940						
1	198	147	13	1	37	90.6
1½	196	145	25	4	22	90.5
2	200	148	19	4	29	90.1
2½	196	148	18	6	24	91.5
3	199	154	21	1	23	91.2
Checks	500	308	0	22	170	66.0
THREE FIELDS OF HYBRID FIELD CORN IN NEW JERSEY, 1940						
2	150	104	15	0	31	69.3
2½	150	110	18	1	21	74.0
3	150	121	9	0	20	80.7
Pyrethrum 0.2 percent (home mixed)	149	118	17	0	14	79.7
Pyrethrum 0.2 percent (commercial mixture)	149	110	18	0	21	74.3
Checks	150	37	1	0	112	24.7

[1] The ears of this field were injured by drought.

In the summer of 1940 oil of 125–135 seconds viscosity containing from 1 to 3 percent of dichloroethyl ether was applied to series of ears in 10 fields of corn in New Jersey. A summary of these results, also, is given in table 30. During this period the degree of infestation of sweet corn by earworms was unusually low, and a relatively large percentage of the treated ears were found to be free from injured kernels, as compared with the occurrence of uninjured ears the preceding spring under conditions of high earworm populations in ears adversely affected by drought. Under the summer conditions in

New Jersey each concentration of dichloroethyl ether in oil gave almost identical results in treatments of sweet corn.

Oil of 125–135 seconds viscosity containing 2, 2½, and 3 percent of dichloroethyl ether was also applied to ears in three fields of hybrid yellow dent field corn during the summer of 1940 (table 30). In these fields infestation by earworms was higher than in the fields of sweet corn previously referred to. The results showed a regular increase in the percentage of ears with uninjured kernels proportionate to the concentration of dichloroethyl ether used in the oil. The results with this chemical are practically identical with those obtained by applications of oil containing 0.2 percent of pyrethrins.

Considering the injury caused to the ears by applications of oil containing more than 3 percent of dichloroethyl ether and the average effectiveness of the different concentrations in protecting the ears against injury by earworms, these studies show that a 3-percent solution would be satisfactory from both viewpoints, but that to allow a margin of safety a 2-percent solution would be preferable for use in commercial applications.

EFFECTIVENESS OF OILS OF DIFFERENT VISCOSITIES

A series of white mineral oils, ranging in viscosity from approximately 50–260 seconds Saybolt, each containing 3 percent of dichloroethyl ether, were applied to replicate series of ears of Golden Cross Bantam in the spring of 1940. The data summarized in table 31, indicate that these different oils are equally satisfactory as carriers of dichloroethyl ether. Although this corn was grown during dry weather, the experiments were run in an irrigated field, and the ears were not affected adversely by weather, the husks being of good length, reasonably tight for this variety, and not at all wilted. These conditions probably account for the high rate of protection afforded the ears by the treatments, even though earworms were abundant. A comparison of the effectiveness of all oils containing dichloroethyl ether in each of five replicates, also given in table 31, indicates that the infestation by earworms was uniform throughout the field and shows that similar results were obtained when applications were made to ears of one variety of corn growing under the same environmental conditions.

EFFECTIVENESS IN DIFFERENT VARIETIES OF CORN

White oil of 200–210 seconds viscosity containing from 1 to 5 percent of dichloroethyl ether was applied to series of ears of three very dissimilar varieties of sweet corn during the summer of 1939. Excellent results were obtained by applications to ears of Bantam Evergreen and a local, white sweet corn, but considerably less favorable results followed applications to Kancross, a variety that has an extremely long husk and an extremely large mass of interior silk.

Oil of 125–135 seconds viscosity containing 2 percent of dichloroethyl ether was applied to ears of nine varieties of sweet corn in New Jersey during the summer of 1940 (table 32). Although the results obtained were variable, the lowest percentage of ears of any one variety found to be without live larvae or with uninjured kernels at time of roasting-ear harvest was 81.7.

TABLE 31.—*Comparison of results obtained in 5 replicates of applications of white oils ranging in viscosity from approximately 50–260 seconds containing 3 percent of dichloroethyl ether in protecting ears of Golden Cross Bantam sweet corn against injury by earworms, when applied at a dosage of 0.75 ml. per ear by a force oiler at a time when the silks were wilted or had browned tips, Florida, 1940*

COMPARISON OF THE OILS

Viscosity of oil (seconds)	Ears	Ears found at time of harvest—				Ears with uninjured kernels
		Without live larvae		With live larvae		
		Kernels uninjured	Kernels injured	Kernels uninjured	Kernels injured	
	Number	*Number*	*Number*	*Number*	*Number*	*Percent*
50–55	250	223	4	4	19	90.8
80–90	247	214	4	5	24	88.7
125–135	250	227	1	5	17	92.8
200–210	250	226	3	1	20	90.8
250–260	247	226	1	6	14	92.7
Checks	250	35	0	5	210	16.0
COMPARISON OF THE REPLICATES [1]						
First	249	207	3	14	25	88.8
Second	250	235	0	5	10	96.0
Third	250	227	6	1	16	91.2
Fourth	245	219	3	0	23	89.4
Fifth	250	225	4	1	20	90.4
All replicates	1,244	1,113	16	21	94	91.2

[1] The ears of replicates were treated and examined as follows: First, May 2 and 14; second, May 5 and 15; third, May 7 and 17; fourth, May 9 and 18; fifth, May 11 and 20.

In the spring of 1941 in Florida, the same combination was applied to ears in several fields of Tuxpan roasting-ear corn and of Golden Cross Bantam sweet corn (table 32). The rate of control obtained was considerably higher in the first variety, probably because the silks of Tuxpan ears were closely compressed by the husks, whereas in the less tightly compressed silks of Golden Cross Bantam ears the larvae could disperse more rapidly to locations within the ears where the oil and insecticide did not reach some of them, resulting in a lower rate of kill and poorer protection.

The same oil containing 2 percent of dichloroethyl ether was applied to series of ears of different varieties of sweet corn in New Jersey during the summer of 1941 (table 32). Here again considerable variation in effectiveness of applications of oil-dichloroethyl ether was observed, due to differences in the characters of the ears in the different varieties and in part to environmental factors affecting growth of the plants.

These results show that although the effectiveness of applications of oil-dichloroethyl ether in ears varied as between varieties, the rate of control was reasonably satisfactory in all the varieties when the ears were not adversely affected by drought or other environmental factors.

DOSAGE PER EAR

White oil of 125–135 seconds viscosity containing 3 percent of dichloroethyl ether was applied to replicate series of Golden Cross Bantam ears in Florida during the spring of 1940, at dosages of 0.50, 0.75, and 1 ml. per ear, resulting in 85.9, 85, and 82 percent,

TABLE 32.—*Effectiveness of applying white oil of 125–135 seconds viscosity containing 2 percent of dichloroethyl ether to ears of several varieties of sweet corn, at a dosage of 0.75 ml. per ear*

Variety of corn	State where grown	Ears	Ears found at time of roasting-ear harvest— Without live larvae: Kernels uninjured	Without live larvae: Kernels injured	With live larvae: Kernels uninjured	With live larvae: Kernels injured	Ears without live larvae	Ears with uninjured kernels
		Number	*Number*	*Number*	*Number*	*Number*	*Percent*	*Percent*
TREATED EARS								
Ioana	New Jersey, 1940	105	98	4	0	3	97.1	93.3
Iowa 45	do	100	87	2	3	8	89.0	90.0
Iogen	do	100	90	1	5	4	91.0	95.0
Iogold A	do	20	18	1	0	1	95.0	90.0
Golden hybrid 2439	do	100	86	7	3	4	93.0	89.0
Golden hybrid 3539	do	100	78	3	4	15	81.0	82.0
Golden hybrid 3839	do	60	49	0	0	11	81.7	81.7
Newjey	do	80	68	6	0	6	92.5	85.0
Maule's Lead All	do	100	92	2	1	5	94.0	93.0
Total		765	666	26	16	57		
Percent			87.1	3.4	2.1	7.4	90.5	89.2
CHECKS UNTREATED EARS								
Ioana	New Jersey, 1940	26	1	1	5	19	7.7	23.1
Iowa 45	do	28	22	0	2	4	78.6	85.7
Iogen	do	37	2	0	8	27	5.4	27.0
Iogold A	do	25	1	0	10	14	4.0	44.0
Golden hybrid 2439	do	17	7	0	6	4	41.2	76.5
Golden hybrid 3539	do	34	0	0	8	26	0	23.5
Golden hybrid 3839	do	34	1	0	17	16	2.9	52.9
Newjey	do	25	0	0	2	23	0	8.0
Maule's Lead All	do	50	3	0	11	36	6.0	28.0
Total		276	37	1	69	169		
Percent			13.4	0.4	25.0	61.2	13.8	38.4
TREATED EARS								
Tuxpan roasting-ear corn	Florida, 1941	100	86	3	6	5	89.0	92.0
Golden Cross Bantam	do	75	55	3	1	16	77.3	74.7
CHECKS								
Tuxpan roasting-ear corn	Florida, 1941	100	0	0	42	58	0	42.0
Golden Cross Bantam	do	75	13	0	8	54	17.3	28.0
TREATED EARS								
Golden Cross Bantam	New Jersey, 1941	81	52	10	7	12	76.5	72.8
Local white sweet corn	do	85	69	5	5	6	87.1	87.1
Yellow sweet corn of unspecified variety.	do	100	49	25	4	22	74.0	53.0
CHECKS								
Golden Cross Bantam	New Jersey, 1941	110	3	0	7	100	2.7	9.1
Local white sweet corn	do	60	7	1	12	40	13.3	31.7
Yellow sweet corn of unspecified variety.	do	50	1	0	2	47	2.0	6.0

respectively, of ears with uninjured kernels, showing that the rates of dosage mentioned were equally effective under the conditions in which these tests were made, and when only 9 percent of the check ears were uninjured.

METHODS OF APPLICATION

In the summer of 1940 white oil of 125–135 seconds viscosity containing 2 percent of dichloroethyl ether was applied to series of ears in five fields of sweet corn by three methods. There was no difference in the degree of protection afforded the ears against injury by earworms when the oil dosage was dropped on the silk at the tip of the ears or injected after the tip of the spout of the oiler had been thrust for ½ inch into the interior silks, the percentage of uninjured kernels being 86.3 and 85.5, respectively. A slightly higher rate of control (94 percent), however, resulted when the tip of the spout was inserted for ¾ inch into the interior silk of the ears before the dosage was released. In the checks 72 percent of the ears were uninjured. In all these cases most of the dosage of oil seeped into the interior silks, little or none being lost through run-off.

AS A CONTACT INSECTICIDE

The first toxicity tests with oil-dichloroethyl ether were made during the summer of 1939. Earworms were collected in the field, isolated in 2-ounce salve boxes similar to those previously employed in toxicity tests of oil-pyrethrins, and each was provided with a section of corn cob bearing tender kernels as food. A small drop of oil-dichloroethyl ether, roughly proportionate to the size of the larva, was applied to the dorsal surface of each earworm. It immediately spread over the larva. The materials used, the instars treated, and the results obtained are given in table 33.

TABLE 33.—*Effectiveness of white oils of different viscosities containing 1 or 2 percent of dichloroethyl ether compared with oils containing 0.1 percent of pyrethrins, as contact insecticides against earworms when a small droplet was applied per larva in toxicity tests, summer of 1939*

Viscosity of oil (seconds)	Insecticide used	Larvae used of instar—			Surviving larvae of instar—			Larvae that died
		5	6	Total	5	6	Total	
		Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*
50–60	2-percent dichloroethyl ether.	2	5	7	0	3	3	57.1
125–135	do	2	6	8	1	0	1	87.5
200–210	do	1	6	7	1	0	1	85.7
5 oils of unspecified viscosity.[1]	do	9	26	35	5	10	15	57.1
125–135	1-percent dichloroethyl ether.	8	3	11	6	2	8	27.3
200–210	do	8	3	11	5	3	8	27.3
50–55	0.1-percent pyrethrins.	2	7	9	0	0	0	100.0
125–135	do	2	6	8	0	0	0	100.0
200–210	do	9	9	18	1	0	1	94.4
Checks	Untreated larvae	5	21	26	4	21	25	3.8

[1] Includes 3 white oils and 2 horticultural oils, the viscosity of which probably was less than 100.

As compared with the results obtained in similar tests in which oil-pyrethrins were used, and as compared with the results obtained in treating sweet-corn ears with oil-dichloroethyl ether in the fields, the toxicity tests seemed to show that oil-dichloroethyl ether was not so effective as a contact insecticide as was oil-pyrethrins. Apparently some other factor, possibly loss of fumigation effect, was involved.

IN RELATION TO DICHLOROETHYL ETHER CONTENT

In the spring of 1940, oils of 125–135 or 200–210 seconds viscosity containing from 1 to 3 percent of dichloroethyl ether were applied by means of a fine camel's hair brush to first instars hatched from eggs collected in the field. The earworms had been placed in watch glasses of about 20-cc. capacity in lots of 10, provided with fresh corn silk as food, and covered with other watch glasses. A higher rate of mortality occurred than in the preliminary trials (table 33) with larger larvae. Similar tests with second or third instars that had been isolated in unventilated 2-ounce salve boxes, in each of which a section of corn cob bearing tender kernels had been placed as food, resulted in the death of all 50 larvae to which the insecticide had been applied.

In a further test during the summer of 1940 the same solutions were each applied to 5 third instars that had been isolated in 2-ounce salve boxes in which numerous small holes had been punched to provide ventilation. Applications of oil of 200–210 seconds viscosity containing 1½, 2½, or 3 percent of dichloroethyl ether caused 100 percent mortality, but that containing 1 or 2 percent caused only 60 percent. Applications of oil of 125–135 seconds viscosity caused 100 percent mortality except for the 1-percent solution, which caused 60 percent mortality.

White oil of 125–135 seconds viscosity containing 3 percent of dichloroethyl ether applied to fifth and sixth instars which were confined singly in ventilated salve boxes, resulted in mortality of 71.7 percent of 46 larvae that were treated. Of 22 fifth instars, 6 of which were newly molted, 50 percent died; and of 24 sixth instars, 15 of which were newly molted, 91.7 percent succumbed.

Earworms of various instars were then confined in salve boxes which were covered with cheesecloth to allow greater ventilation, and oil of 125–135 seconds viscosity containing 3 percent of dichloroethyl ether was applied to them in the manner previously described. This treatment resulted in no mortality of 9 third instars, 5.9 percent mortality of 17 fourth instars, 23.8 percent mortality of 21 fifth instars, and 30.8 percent mortality of 13 sixth instars, or an average of 16.7 percent mortality for 60 larvae of all stages of development.

In the summer of 1941 similar treatments of fifth and sixth instars with white oil of 125–135 seconds viscosity containing 2 percent of dichloroethyl ether, resulted in mortality of 88 percent of 25 larvae treated in unventilated salve boxes and of 80 percent mortality of 20 treated in ventilated salve boxes.

IN RELATION TO VISCOSITY OF OIL

In the spring of 1940 white oils ranging in viscosity from approximately 50–260 seconds, each containing 3 percent of dichloroethyl ether, were applied to earworms of various instars which had been collected from corn ears in the field and isolated in unventilated 2-ounce salve boxes, as described for the previous tests. The results of these tests are summarized in table 34. The mortality of larvae resulting from these treatments showed that although oils ranging in viscosity from about 50–210 seconds were equally effective carriers of dichloroethyl ether, an oil of 250–260 seconds viscosity was less effective. The results also showed that fifth and sixth instars succumbed to the treatment in larger numbers than did the smaller instars.

TABLE 34.—*Effectiveness of mineral oils containing 3 percent of dichloroethyl ether, in killing earworms in toxicity tests, Sanford, Fla., 1940*

Viscosity of oil used (seconds)	Instar treated	Stage of development in instar: Newly molted	Medium	Premolt	Total	Mortality
		Number	*Number*	*Number*	*Number*	*Percent*
50-60	2	0	6	4	10	90.0
	3	2	6	2	10	80.0
	4	9	8	3	20	90.0
	5	3	15	2	20	75.0
	6	10	0	0	10	100.0
Total		21	35	11	70	85.7
80-90	2	2	4	4	10	80.0
	3	1	1	5	10	90.0
	4	2	15	3	20	85.0
	5	1	11	5	20	90.0
	6	8	2	0	10	100.0
Total		17	36	17	70	88.6
125-135	2	0	3	7	10	60.0
	3	2	5	3	10	60.0
	4	3	11	6	20	70.0
	5	3	11	6	20	100.0
	6	8	2	0	10	100.0
Total		16	32	22	70	80.0
200-210	2	0	4	6	10	70.0
	3	3	3	4	10	50.0
	4	1	13	6	20	65.0
	5	3	13	1	20	100.0
	6	9	1	0	10	100.0
Total		16	34	20	70	78.6
250-260	3	1	5	4	10	50.0
	4	3	12	5	20	55.0
	5	0	12	8	20	70.0
	6	8	2	0	10	100.0
Total		12	31	17	60	66.7
All oils	2	2	17	21	40	75.0
	3	9	23	18	50	66.0
	4	18	59	23	100	73.0
	5	13	62	25	100	87.0
	6	43	7	0	50	100.0

AS A FUMIGANT

The results of the toxicity tests so far described seem to show that oil containing dichloroethyl ether acted partly as a fumigant in some cases, such as in the experiments summarized in table 34. In this case it seems clear that since a larger dosage of oil-dichloroethyl ether was applied in proportion as the larvae were larger, the concentration of vapor within the closed containers reached a point where, in the case of sixth instars, it was fatal to all the individuals treated. The smaller dosage applied to smaller larvae seemingly often failed to provide a sufficient concentration of vapor to kill all of them

To study the effectiveness of dichloroethyl ether in oil solely as a fumigant, under conditions where it did not actually come into contact with the larvae, earworms were collected in the field and isolated in unventilated salve boxes with food. The separable parts of several No. 0 gelatin capsules were perforated with many small holes and a ball of absorbent paper of suitable size, into which 3 drops of a 3-percent solution of dichloroethyl ether in white oil of 125–135 seconds viscosity was injected, was placed in each. Each half-capsule was then plugged with unimpregnated absorbent paper. One of these was placed in each salve box containing a larva. Of 18 third, 37 fourth, 34 fifth, and 11 sixth instars, or a total of 100 larvae, all succumbed to this treatment. The larvae in this case could not have come into contact with the oil-dichloroethyl ether.

In another test larvae collected as previously described were isolated in unventilated 2-ounce salve boxes with food, in each of which was placed a small ball of absorbent paper impregnated with only 1 drop of white oil of 125–135 seconds viscosity containing 3 percent of dichloroethyl ether. Examination on the day following treatment showed a mortality of 42.9 percent of 7 third instars, 76.9 percent of 13 fourth instars, 41 percent of 39 fifth instars, and 84.2 percent of 19 sixth instars, or a mortality of 57.7 percent of 78 larvae.

In the summer of 1940 another test was made of the same solution as a fumigant at rates of from 1 to 3 drops per cage, by use of the half-capsule method in unventilated 2-ounce salve boxes. In this test, with 20 larvae treated at each dosage, 1 drop killed 60 percent, 2 drops 90 percent, and 3 drops 100 percent. With the 1-drop dose the percentages of mortality were 100, 85.7, 33.3, and 0 for larvae of the third, fourth, fifth, and sixth instars, respectively.

DISCUSSION OF DICHLOROETHYL ETHER

The results of all the toxicity tests against earworms seem to show that when oil-dichloroethyl ether is applied to ears of sweet corn this material probably kills both by contact and by fumigation. This probably explains why dichloroethyl ether in oil is more effective than materials which act only as fumigants.

In general, the results of the experiments that have been described indicate that under usual conditions the protection afforded sweet-corn ears by applications of white oil containing 2 percent of dichloroethyl ether is at least equal to that afforded by applications of oil containing 0.2 percent of pyrethrins. Two percent of dichloroethyl ether could be added to a gallon of oil at a cost of about 6 cents as compared with a cost of from 40 to 50 cents for the addition of 0.2 percent of pyrethrins per gallon. As will be discussed in detail later on, however, oil-dichloroethyl ether proved to be more hazardous than oil-pyrethrins from the standpoint of objectionable residues that might be left on the kernels at time of roasting-ear harvest. Although it has an advantage over oil-pyrethrins in the matter of cost, the oil-dichloroethyl ether could not be recommended unreservedly, and it was believed that other materials might be found which, when used in mineral oil, would cost less than oil-pyrethrins and would be free from the residue hazard of oil-dichloroethyl ether.

MINERAL OIL CONTAINING OTHER MATERIALS

When used in the field, dichloroethyl ether did not evaporate rapidly enough under some conditions to be entirely eliminated from the ears by the time of roasting-ear harvest, probably because of its boiling point of 145° C. (319.67° F.). It was believed that the hazard of undesirable residue might be overcome by the use of substances having a lower boiling point, such as diethyl ether (94.1° F.) or trichloromethane (142.2° F.). Many other substances, including ethylene chlorohydrin (boiling point, 128.8° F.), two ketones, several thiocyanates, and rotenone were studied. The results obtained by use of the more important of these materials in mineral oil will now be discussed.

DIETHYL ETHER

During the summer of 1940 diethyl ether was used in New Jersey at a concentration of 2 percent in mineral oil of 125–135 seconds viscosity, and its effectiveness was compared with that of oil-pyrethrins and oil-dichloroethyl ether. Earworm infestation during this time was light. In five fields of sweet corn in which replicate applications were made, from 10 to 66 percent of the check ears were free from infestation, and from 28 to 94 percent were free from kernel injury at time of roasting-ear harvest. The results of replicate applications of oil-diethyl ether in the five fields are given in table 35. Under the stated conditions this material in oil gave protection to as high or a higher percentage of treated ears as did oil-pyrethrins or oil-dichloroethyl ether.

TABLE 35.—*Effectiveness of applications of white oil of 125–135 seconds viscosity containing diethyl ether or trichloromethane, as compared with dichloroethyl ether and pyrethrins, in protecting sweet-corn ears against injury by earworms when applied to replicate plots in 5 fields at a dosage of 0.75 ml. by force oiler, at a time when silks were wilted, New Jersey, 1940*

Material used in oil	Strength	Ears examined	Ears at time of roasting-ear harvest— Without live larvae: Kernels uninjured	Without live larvae: Kernels injured	With live larvae: Kernels uninjured	With live larvae: Kernels injured	Ears without live larvae	Ears with uninjured kernels
	Percent	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*	*Percent*
Diethyl ether	2.0	225	191	2	0	23	85.8	88.0
Trichloromethane	2.0	225	183	3	0	30	82.7	85.3
Dichloroethyl ether	2.0	250	217	12	2	10	91.6	87.6
Pyrethrins[1]	0.2	199	172	8	4	15	90.5	88.4
Checks		250	95	0	60	95	38.0	62.0

[1] A commercial preparation applied to 4 replicates only.

A second series of tests were made in Florida during the spring of 1941, in which diethyl ether was evaluated at concentrations of from 2 to 10 percent in mineral oil of 125–135 seconds viscosity and applied to ears in three fields of Tuxpan roasting-ear corn and three fields of Golden Cross Bantam sweet corn. The results of these treatments are summarized in table 36.

When applied to ears of Tuxpan the effectiveness of oil-diethyl ether increased roughly in proportion to its percentage content in oil; however, this was not the case when applications were made to ears of Golden Cross Bantam. The average results recorded at roasting-ear harvest from all mentioned concentrations of oil-diethyl ether showed, for Tuxpan corn, 73.9 percent ears without live larvae and 85.4 percent with uninjured kernels, and for Golden Cross Bantam 66.4 percent of ears without live larvae and 64 percent with uninjured kernels.

TABLE 36.—*Effectiveness of applications of white oil of 125–135 seconds viscosity containing various materials, in affording protection against earworm injury to ears of sweet or roasting-ear corn, when applied at a dosage of 0.75 ml., Florida, 1941*

Material used in oil	Strength	Rate of protection afforded to ears when applied to— Tuxpan roasting-ear corn: Ears examined	Tuxpan roasting-ear corn: Ears without live larvae	Tuxpan roasting-ear corn: Ears with uninjured kernels	Golden Cross Bantam sweet corn: Ears examined	Golden Cross Bantam sweet corn: Ears without live larvae	Golden Cross Bantam sweet corn: Ears with uninjured kernels
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*
Diethyl ether	2	68	72.1	79.4	75	73.3	73.3
Do	3	72	73.6	87.5	75	70.7	65.3
Do	4	73	67.1	82.2	75	69.3	69.3
Do	5	75	70.7	85.3	75	50.7	52.0
Do	6	25	76.0	80.0	25	64.0	56.0
Do	8	24	83.3	95.8	25	76.0	68.0
Do	10	25	80.0	100.0	25	64.0	56.0
Trichloromethane	2	70	80.0	90.0	75	66.7	61.3
Do	3	72	75.0	86.1	75	62.7	66.7
Do	4	74	81.1	86.5	75	70.7	69.3
Do	5	72	77.8	90.3	75	66.7	64.0
Do	6	25	88.0	100.0	25	64.0	56.0
Do	8	[1] 25	72.0	96.0			
Do	10	[2] 25	80.0	96.0			
Ethylene chlorohydrin	2	73	65.5	84.8	50	52.0	54.0
Do	3	75	84.0	89.3	50	60.0	58.0
Morpholine	1	23	78.3	91.3	50	80.0	76.0
Pyrethrins [3]	0.2	340	93.2	95.6	373	81.2	77.5
Dichloroethyl ether	2	100	89.0	92.0	75	77.3	74.7
Checks—untreated ears		100	0	42.0	75	17.3	28.0

[1] Interior silks of 17 ears were rotted.
[2] Interior silks of 21 ears were rotted.
[3] Average results of treatments using 5 lots of material.

TABLE 37.—*Effectiveness of applications of white oil of 125–135 seconds viscosity containing various materials, in affording protection against injury by earworms to ears of 4 replicated plots in 3 fields of Golden Cross Bantam and 1 of local white sweet corn, when applied at a dosage of 0.75 ml., New Jersey, 1941*

Material used in oil	Strength	Ears	Ears found in the stated condition at time of roasting-ear harvest—Without live larvae: Kernels uninjured	Without live larvae: Kernels injured	With live larvae: Kernels uninjured	With live larvae: Kernels injured	Ears without live larvae	Ears with uninjured kernels
	Percent	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*	*Percent*
Diethyl ether	3	99	26	4	13	55	30.30	39.39
Do	5	100	36	6	11	47	42.00	47.00
Trichloromethane	3	100	39	1	10	50	40.00	49.00
Do	5	99	47	6	18	28	53.53	65.65
Ethylene chlorohydrin	2	100	60	11	8	21	71.00	68.00
Do	3	100	50	12	12	26	62.00	62.00
Do	4	99	53	10	9	27	63.63	62.62
Do	5	99	59	5	7	28	64.64	66.67
Morpholine	1	100	39	7	7	47	46.00	46.00
Do	2	98	45	3	5	45	48.98	51.02
Do	3	99	36	10	10	43	46.46	46.46
Dichloroethyl ether	2	266	170	40	16	40	78.95	69.92
Pyrethrins [1]	0.2	320	218	40	14	48	80.62	72.50
Checks		370	15	2	30	323	4.59	12.16

[1] A commercial preparation used for comparison.

Another test in New Jersey during the summer of 1941 (table 37) showed diethyl ether in much less favorable light than had the results of the two previous tests. Diethyl ether, however, has an advantage over dichloroethyl ether in that usually it evaporates entirely from the ears by roasting-ear harvest. No injury to the ears resulted from the applicntion of 5 percent by volume in oil. Although still considered a promising material, diethyl ether has not given as consistently good results in affording protection against earworm injury to sweet-corn ears as has either oil-pyrethrins or oil-dichloroethyl ether.

TRICHLOROMETHANE

Trichloromethane was first studied at a concentration of 2 percent in white oil of 125-135 seconds viscosity during the summer of 1940, when applications were made to series of ears in five fields of sweet corn in comparison with oil-pyrethrins and oil-dichloroethyl ether (table 35). In these first tests, during a time of light infestation by earworms, trichloromethane gave nearly as good protection against earworm injury to sweet-corn ears as did oil-diethyl ether, oil-pyrethrins, or oil-dichloroethyl ether.

In the spring of 1941 in Florida, trichloromethane, at concentrations ranging from 2 to 10 percent in white mineral oil of 125-135 seconds viscosity, was applied to series of ears in three fields of Tuxpan roasting-ear corn, and at concentrations of from 2 to 6 percent in this oil it was applied to series of ears of Golden Cross Bantam. Concentrations of 8 and 10 percent burned the husks and caused rotting of the interior silks, but concentrations ranging from 2 to 6 percent caused no injury. The results in these treatments are given in table 36. In general the degree of protection afforded the ears against injury by earworms was not at all proportionate to the trichloromethane content in the oil. The average results obtained by using this material at all the concentrations in oil tested were, for Tuxpan, 78.8 percent ears without live larvae and 90.1 percent with uninjured kernels; and for Golden Cross Bantam, 66.5 percent of treated ears without live larvae and 64.6 percent with uninjured kernels.

In the summer of 1941 in New Jersey, white oil of 125-135 seconds viscosity containing 3 or 5 percent of trichloromethane was applied to series of ears in four fields of sweet corn (table 37). Here this material gave consistently more satisfactory results at both concentrations than had similar concentrations of diethyl ether in the same oil. In table 37 it is compared with diethyl ether, dichloroethyl ether, pyrethrins, ethylene chlorohydrin, and morpholine used in the same fields.

Although the 5-percent solution of oil-trichloromethane gave somewhat better protection than the 3-percent solution, the performance of oil-trichloromethane fell considerably short of the protection afforded by oil pyrethrins or by oil-dichloroethyl ether. In general, trichloromethane used in mineral oil seemed to be somewhat more promising under various conditions than oil-diethyl ether. As was the case with oil-diethyl ether, the trichloromethane applied to sweet corn was found to have evaporated entirely by harvest, and no residue of this material was detected on roasting ears.

ETHYLENE CHLOROHYDRIN

Ethylene chlorohydrin, used at concentrations of 2 or 3 percent in mineral oil of 125–135 seconds viscosity, was applied to series of ears of Tuxpan roasting-ear corn and Golden Cross Bantam sweet corn during the spring of 1941. The results (table 36) seemed to be rather promising. In New Jersey, in the summer of 1941, sweet corn was treated with white oil containing ethylene chlorohydrin at concentrations ranging from 2 to 5 percent, with results as given in table 37. In these tests oil-ethylene chlorohydrin was somewhat more effective than were oil-diethyl ether or oil-trichloromethane, and this was particularly true when the percentages of the larval populations found dead in the ears at roasting-ear harvest were considered, as shown in table 38. The information obtained, especially that from the summer experiments, did not show that the effectiveness of this mixture was in proportion to the content of ethylene chlorohydrin, either in the protection of ears against injury or in the percentage of larvae found dead in the ears at harvest. Although the results with oil-ethylene chlorohydrin seemed to be promising, the degree of control was scarcely comparable to that obtained by applications of oil-pyrethrins or oil-dichloroethyl ether.

TABLE 38.—*Effectiveness of various materials used in mineral oil of 125–135 seconds viscosity in applications to ears of sweet corn, as determined by the percentages of the larval populations found dead at time of roasting-ear harvest, New Jersey, summer of 1941*

Material used in oil	Strength	Ears examined	Larvae found in the ears	Larvae found dead
	Percent	*Number*	*Number*	*Percent*
Pyrethrins	0.2	95	160	88.12
Dichloroethyl ether	2.0	96	173	87.22
Diethyl ether	3.0	99	145	42.07
Do	5.0	100	141	51.06
Trichloromethane	3.0	100	143	50.35
Do	5.0	99	158	63.92
Ethylene chlorohydrin	2.0	100	134	73.88
Do	3.0	100	145	71.72
Do	4.0	99	153	73.86
Do	5.0	99	153	75.16
Morpholine	1.0	100	157	64.97
Do	2.0	98	145	61.38
Do	3.0	99	147	60.54
Checks		100	132	1.51

MORPHOLINE

Morpholine, a colorless liquid having a boiling point of 264.0° F., was studied first in the spring of 1941, when a 1-percent solution in white mineral oil of 125–135 seconds viscosity was applied in Florida to series of ears of Tuxpan roasting-ear corn and of Golden Cross Bantam. The results are summarized in table 36. In the summer of 1941 this material was used at concentrations ranging from 1 to 3 percent in series of tests in New Jersey (table 37). The percentages of the larval populations found dead in treated ears at time of roasting-ear harvest are shown in table 38. Although in the spring trials this material seemed to show promising results, it gave unfavorable results during the summer when used under different conditions.

KETONES

In the spring of 1940 two colorless liquids, methyl n-amyl ketone (boiling point, 303° F.) and methyl isobutyl ketone (boiling point, 241° F.), were used in white oil of 200–210 seconds viscosity at concentrations of 3 percent, when applications were made to series of ears of Golden Cross Bantam sweet corn. The results are given in table 39.

TABLE 39.—*Effectiveness of applications of white oil of 200–210 seconds viscosity containing 3 percent of 2 ketones, to ears of Golden Cross Bantam sweet corn at a dosage of 0.75 ml. per ear in protecting the ears against earworm injury, Sanford, Fla., 1940*

Material used in oil	Ears examined [1]	Ears found at time of roasting-ear harvest —				Ears with uninjured kernels
		Without live larvae		With live larvae		
		Kernels uninjured	Kernels injured	Kernels uninjured	Kernels injured	
	Number	*Number*	*Number*	*Number*	*Number*	*Percent*
Methyl n-amyl ketone	100	80	1	0	19	80.0
Methyl isobutyl ketone	100	72	0	1	27	73.0
Dichloroethyl ether [2]	500	462	6	6	26	93.6
Checks	100	11	0	0	89	11.0

[1] 2 replicates of 50 ears each.
[2] This line includes all treatments using oil containing 3 percent of dichloroethyl ether in this field on the same dates.

Applications of 3- or 5-percent concentration in white oils of 125–135 and 200–210 seconds viscosity were also made to series of ears of Truckers' Favorite. In these tests the effectiveness of these materials seemed to increase somewhat in proportion as concentrations were greater, and both of them apparently afforded a promising degree of protection against earworm injury. These materials were also applied in the spring of 1941 at concentrations of 2 or 3 percent in white oil of 125–135 seconds viscosity, to Tuxpan roasting-ear corn and Golden Cross Bantam sweet corn. The results with the two ketones seemed to be rather promising, those with methyl n-amyl ketone being slightly more satisfactory than those with methyl isobutyl ketone. It was found, however, that the latter material sometimes imparted an unpleasant flavor to the kernels of treated ears, so it is doubtful whether these chemicals could be recommended safely for practical use.

THIOCYANATES

Four materials obtained in proprietary preparations, including 2-(2-butoxyethoxy)ethyl ester of thiocyanic acid, naphthyl isothiocyanate, fenchyl thiocyanate, and an unspecified material, were used in white oil to evaluate their effectiveness in earworm control. They were used alone in white oil and also to replace part of the pyrethrin content of oil pyrethrum mixtures, to determine whether the cost of oil-pyrethrum treatment could be reduced and the effectiveness of the mixtures still maintained. It was found that all the thiocyanates tested, when used alone in oil at concentrations sufficient to kill a large percentage of the larvae in the ears and to protect a large percentage of the ears against injury by earworms, burned the husks and caused rotting of the interior silks. The results also indicated that the thiocyanates studied would not be useful in replacing part of the pyrethrum in oil-pyrethrum mixtures.

NICOTINE AND ROTENONE

On several occasions nicotine sulfate (50 percent free nicotine) has been combined with mineral oil and applied to sweet-corn ears. No evidence was obtained that nicotine increased the effectiveness of the oil, or that it had value as an insecticide against earworms. A similar conclusion was reached regarding rotenone. Both when combined with mineral oil and when used in aqueous solutions, rotenone appeared to have no insecticidal value against earworms.

INFLUENCE OF HUSK CHARACTERS ON EARWORM CONTROL

The husk characters of sweet-corn ears have been referred to frequently in the foregoing discussion. This has been necessary because, excepting the insecticide employed, no other factor is more important in earworm control. The character of the husk influences not only the volume and condition of the interior silk and the habits of the larvae after they enter the ears, but also the distribution and effectiveness of any insecticide that is applied to the silk. Many measurements of the extension of the husk beyond the tip of the cob of sweet-corn ears were made at the time of roasting-ear harvest, in different varieties grown in different localities. Records also were taken of the larvae present, with respect to their stages of growth, location in relation to the husk tip and cob tip, and the fate of those found in treated and in check ears.

Influence on Percentage of Larvae That Reach Cobs

When mineral oil containing insecticides, especially oil-pyrethrins, is applied to the silks of sweet-corn ears, any larvae present usually are killed where they were feeding at the time the insecticide was applied. Measurements of the husk extension and similar records of the feeding locations of larvae that had been killed by insecticides were made on a variety of local, white sweet corn during the summer of 1941. The information obtained is given in table 40, which shows, in comparison with husk extension in inches, the percentage of larvae of each instar that reached the kernels.

It was shown that the proportion of larvae that had reached the kernels varied directly with their size and inversely with the length of the husk beyond the tip of the cob. No larvae reached the kernels in 73 ears having husks extending for 4.6 inches or more beyond the cob tips at time of roasting-ear harvest, although these ears contained 102 of the dead larvae, or 18.44 percent of the whole number found.

The percentages of dead earworms of each instar found on the kernels in treated ears of Golden Cross Bantam are also included in table 40. A higher proportion of the larvae from the second to the sixth instar reached the kernels in Golden Cross Bantam ears than in those of the varieties having longer husks, even though it was observed that at time of treatment the larvae were much larger, on an average, in ears of the latter varieties. The distribution of larvae in the check ears of these varieties examined at the same time showed that by time of harvest 97.84 percent of larvae had reached the kernels in untreated ears of Golden Cross Bantam, whereas only 76.29 percent had reached the kernels in the untreated ears of the long-husked local, white sweet corn.

TABLE 40.—*Relation of husk extension beyond the cob of sweet-corn ears at time of roasting-ear harvest to percentage of earworm populations that had reached the kernels by the time of application of insecticide and were killed there by the treatment*

LOCAL, WHITE SWEET CORN, RIVERSIDE, N. J., 1911

Extension of the husk beyond the cobs (inches)[1]	Larvae of stated instars observed and percentages that reached kernels													
	First		Second		Third		Fourth		Fifth		Sixth		Total	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
1.1 to 1.5	0	0	1	100.0	1	0	5	80.0	0	0	2	100.0	9	77.7
1.6 to 2.0	0	0	1	0	2	0	4	100.0	2	100.0	0	0	9	66.7
2.1 to 2.5	0	0	2	50.0	11	18.2	15	46.7	10	50.0	2	50.0	40	40.0
2.6 to 3.0	0	0	9	0	14	35.7	37	27.0	25	32.0	6	83.3	91	30.8
3.1 to 3.5	1	0	11	0	33	21.2	50	22.0	42	12.9	13	61.5	150	29.3
3.6 to 4.0	0	0	7	0	15	0	26	23.1	23	21.7	16	43.8	93	20.4
4.1 to 4.5	0	0	1	0	9	0	11	11.3	26	19.2	9	11.1	59	13.5
4.6 to 5.0	2	0	1	0	6	0	2	0	17	0	1	0	29	0
5.1 to 5.5	0	0	3	0	9	0	10	0	12	0	4	0	38	0
5.6 to 6.0	0	0	1	0	3	0	8	0	6	0	0	0	18	0
6.1 to 6.5	0	0	0	0	4	0	3	0	1	0	1	0	9	0
6.6 to 7.0	0	0	0	0	0	0	1	0	1	0	2	0	4	0
7.1 to 7.5	0	0	0	0	0	0	3	0	0	0	0	0	3	0
7.6 to 8.0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
Total	3	0	37	5.4	107	13.1	179	21.6	171	25.7	56	42.9	553	23.2
GOLDEN CROSS BANTAM SWEET CORN, BURLINGTON COUNTY, N. J.														
(2)		0		15.8		31.5		51.0		59.2		100.0		33.8

[1] Average extension 3.7.

[2] Average extension 1.8.

TABLE 41.—*Relation of husk extension beyond the cob to the dispersion of oil to the cobs and distances of penetration into sweet-corn ears when the oil was applied in different places to ears; white oil of 125-135 seconds viscosity containing 2 percent of dichloroethyl ether and colored with Sudan 3 stain was applied at a dosage of 0.75 ml. per ear; New Jersey, 1940*

Husk extension beyond the cob (inches)	Average penetration of oil in ears to which applications were made in the stated manner											
	Dropped on silks at ear tip				Injected ¼ inch				Injected ¾ inch			
	Ears examined	Penetration			Ears examined	Penetration			Ears examined	Penetration		
		On cobs below tip	In ears below husk tip	Cobs free of oil		On cobs below tip	In ears below husk tip	Cobs free of oil		On cobs below tip	In ears below husk tip	Cobs free of oil
	Number	*Inches*	*Inches*	*Percent*	*Number*	*Inches*	*Inches*	*Percent*	*Number*	*Inches*	*Inches*	*Percent*
0	2	2.35	2.35	0	1	1.50	1.50	0	0			
0.1 to 0.5	0				1	1.60	1.60	0	0			
0.6 to 1.0	7	1.50	2.30	0	5	1.02	2.54	0	4	1.58	2.48	0
1.1 to 1.5	8	1.23	2.15	0	13	1.44	2.84	0	10	1.51	2.80	0
1.6 to 2.0	26	1.16	3.27	0	31	1.53	3.41	0	23	1.50	3.37	8.70
2.1 to 2.5	42	1.20	3.53	7.14	48	1.21	3.50	6.25	48	1.60	3.90	0
2.6 to 3.0	60	1.13	3.85	11.67	63	1.25	4.07	9.52	58	1.57	4.30	5.17
3.1 to 3.5	42	.90	4.18	21.43	39	.84	4.11	30.77	48	1.08	4.32	20.83
3.6 to 4.0	26	.80	4.57	42.31	25	.40	4.21	60.00	29	1.21	4.09	17.24
4.1 to 4.5	14	.75	5.00	42.86	14	.41	4.62	64.29	11	.73	4.91	55.56
4.6 to 5.0	11	.48	5.26	54.54	7	0	4.84	100.00	5	.84	5.72	40.00
More than 5.0	11	.08	5.88	90.91	1	0	5.10	100.00	11	.72	6.80	42.86
Total or weighted average	249	1.03	4.01	20.88	248	1.06	3.84	21.37	248	1.35	4.35	13.31

It appears from the evidence just given that the extension of the husk beyond the tip of the cob is an important factor in the protection of the ears from injury by earworms, when an oil-insecticide is used, since the larvae feed for longer periods in the interior silks of the long-husked ears, where more of them can be killed by an insecticide before they reach and injure the kernels.

Influence on Penetration of Oil Into Ears

The penetration of oil insecticides into sweet-corn ears and the frequency with which oil reached the cobs in relation to the extension of the husks, measured at time of roasting-ear harvest, was studied during the summer of 1940. Oil containing 2 percent of dichloroethyl ether plus Sudan 3 stain, which left a red deposit, was applied to the ears at a dosage of 0.75 ml. per ear, at a time when the silks were wilted. Records of the distances to which the oil penetrated into the ears are given in table 41. It was found that, in general, in proportion as the husks were longer the oil penetrated farther into the silk mass but reached fewer of the cobs, as also shown in table 41.

Where the oil did reach the kernels it was usually found on one side of the cob and not evenly distributed on all parts of the tip. Evidently oil will reach larvae in the silk more effectively than it will those on the kernels. Therefore a larger percentage of the earworms can be destroyed by the insecticide if they are all in the interior silks, as in the case of long-husked ears, and relatively fewer can be killed if they have dispersed to the kernels, as in the case of short-husked ears. This is borne out in examinations of thousands of treated ears having variously developed husks.

Husk Extension and Dosage per Ear

The degree of protection afforded sweet-corn ears having good or poor husk coverage by application of white oil of 200-210 seconds viscosity at dosages ranging from 0.2 to 1 ml., was studied during the summer of 1938, and the results obtained are given in table 42.

Table 42.—*Relation of the husk character of sweet-corn ears to effectiveness of applications of from 0.2 to 1 ml. of white oil of 200–210 seconds viscosity made by pipette, New Jersey, summer of 1938*

Dosage of oil per ear (ml.)	Ears examined	Ears having good husk protection [1]		Ears having poor husk protection [2]	
		Ears of this type	Ears protected	Ears of this type	Ears protected
	Number	*Percent*	*Percent*	*Percent*	*Percent*
0.2	80	43.75	80.0	56.25	46.7
0.4	80	41.25	93.9	58.75	46.8
0.6	80	51.25	92.7	48.75	43.6
0.8	90	41.11	97.3	58.89	30.2
1.0	90	45.56	95.1	54.44	34.7
All dosages	420	44.52	92.0	55.48	30.9
Checks	148	46.62	8.7	53.38	3.8

[1] Ears with husk extension of 2 inches or more beyond the tip of the cob, and relatively tight.
[2] Ears with husk extension of less than 2 inches beyond the tip of the cob, and relatively loose.

In ears with husks that extended for at least 2 inches beyond the cobs at time of roasting-ear harvest and were comparatively tight, the rate of protection against injury by earworms increased somewhat in proportion to the increase in dosage. This was not true of ears having husks that extended for less than 2 inches beyond the cobs and were comparatively loose. The remarkable difference (92 as against 40 percent) in the average degree of protection afforded ears of the two classes by applications of oil alone was due to the fact that in the ears having longer, tighter husks the oil saturated and remained suspended in the interior silks by capillary attraction and smothered the earworms that were feeding there, whereas in the ears having short, loose husks the oil seeped through the silks and dispersed farther into the ears, where its effectiveness was lost, because the silk strands were too far apart to retain it as a film about them. Consequently, many of the larvae that were feeding in these silks, although wetted by the oil, were not smothered and continued to feed.

TABLE 43.—*Relation of husk character to effectiveness of application of 0.75 ml. per ear of white oils, ranging in viscosity from 125–345 seconds, to ears of 8 fields of sweet corn and 2 fields of field corn treated for the corn earworm in replicated plots in New Jersey during the summer of 1938*

Field	Variety	Date examined	Ears examined	Ears having good husk protection[1]		Ears having poor husk protection	
				Ears of this type	Ears protected	Ears of this type	Ears protected
	TREATED EARS						
			Number	*Percent*	*Percent*	*Percent*	*Percent*
1	Golden Cross Bantam	Aug. 20	300	40.7	76.4	59.3	14.9
2	Local white sweet	do	300	61.3	93.5	38.7	40.0
3	Big Yellow Dent	Aug. 21	300	56.3	93.0	43.7	42.0
4	Golden Cross Bantam	Sept. 10	300	59.0	96.6	41.0	62.5
5	do	Aug. 19	300	40.3	71.5	59.7	16.9
6	Local white sweet	do	300	60.0	92.5	40.0	46.1
7	Big Yellow Dent	Aug. 21	300	51.3	92.7	48.7	39.6
8	Golden Cross Bantam	Sept. 9	300	38.7	71.2	61.3	14.7
9	do	Aug. 16	170	43.5	86.4	56.5	28.1
10	do	Sept. 10	300	44.3	95.6	55.7	48.2
	Total or weighted average, all fields		2,870	49.8	88.5	50.2	33.2
	CHECKS—UNTREATED EARS						
1	Golden Cross Bantam	Aug. 20	50	40.0	[2]0	60.0	[2]0
2	Local white sweet	do	50	58.0	13.8	42.0	4.8
3	Big Yellow Dent	Aug. 21	50	54.0	11.0	46.0	0
4	Golden Cross Bantam	Sept. 10	50	62.0	29.0	38.0	15.8
5	do	Aug. 19	50	38.0	5.3	62.0	0
6	Local white sweet	do	50	68.0	23.5	32.0	6.3
7	Big Yellow Dent	Aug. 21	50	36.0	0	64.0	6.2
8	Golden Cross Bantam	Sept. 9	50	46.0	8.7	54.0	0
9	do	Aug. 16	49	100.0	0	0	0
10	do	Sept. 10	50	40.0	30.0	60.0	10.0
	Total and average, all fields		499	54.1	12.1	45.9	3.7

[1] Ears were classified into two grades by observation of the length and tightness of the husks: (1) those having good husk protection, being provided with longer, tighter husks, and (2) those having poor husk protection, being provided with shorter, looser husks.

[2] Figures in this column of the untreated ears refer to uninfested ears or ears in which larvae had fed only in the silks. The protection here was provided by the husks alone.

HUSK CHARACTERISTICS AND METHOD OF APPLICATION

As shown in table 42, little difference was found in the distribution of oil in the ears or in the frequency with which it reached the cobs, whether the dosage was dropped on the exterior silks at the tip of the husks or injected into the interior silks for ½ inch. When injected into the interior silk for ¾ inch, however, the oil generally dispersed farther into the ears and reached the cobs more frequently. In 249 ears with average husk extension of 2.9 inches at time of roasting-ear harvest, the oil dropped on the silks at the husk tip reached the tip of the cob in 79.1 percent of the ears; in 248 ears with an average husk extension of 2.8 inches, the oil injected ½ inch into the interior silk reached the tip of the cob in 78.6 percent of the ears; and in 248 ears with average husk extension of 3 inches, the oil injected ¾ inch into the interior silk reached the tip of the cob in 86.7 percent of the ears.

Influence of Husk Characteristics on Control in Different Varieties

In the summer of 1938, ears to which white oils had been applied were graded roughly into two classes according to whether the husks afforded good or poor protection, that is, whether they were relatively long and tight or short and loose. It was found (table 43) that, on an average, approximately 2.7 times as many ears having good husk protection were uninjured by earworms as was the case with ears having poor husk protection.

In every variety and field examined, the treatment was more successful in the ears having good husk protection than in ears having poor husk protection. That the husk itself afforded some protection against injury was shown by the records of check ears in which an average of 3.3 times as many ears having good husk protection were uninjured at time of roasting-ear harvest as was the case with ears having poor husk protection. This shows the great importance of the husk character and indicates that varieties in which a large proportion of the ears are provided with relatively long, tight husks can be protected much more successfully by oil application than can varieties in which a small proportion of the ears are provided with husks of this type. Evidently, when environmental factors affect the ears adversely, so that husks which normally are relatively long and tight become shorter and looser, control of earworms by oiling probably will be relatively less successful.

Husk Characteristics and Viscosity of Oil

In the experiments during the summer of 1938 referred to in the preceding section, the white oils used ranged in viscosity from approximately 125–345 seconds. The examination of the ears, graded into the two classes according to whether the husks were long and tight or short and loose, showed that a similar rate of earworm control had been obtained in the ears of each class, regardless of the viscosity of the oil.

Husk Characteristics in Relation to Effectiveness of Insecticides

In the summer of 1941 white oil of 125–135 seconds viscosity, containing a material that had been found to be effective against earworms as a contact insecticide only (pyrethrins) or a material which had been found to act at least in part as a fumigant (dichloroethyl ether, diethyl ether, or trichloromethane) was applied to series of ears in several fields of a variety of sweet corn having relatively short husks, and to series of ears in several fields of a variety having relatively long husks. As shown in table 44, when oil-pyrethrum was

TABLE 44.—*Relation of husk length to protection of sweet-corn ears against earworm injury by use of white oil of 125–135 seconds viscosity containing a contact insecticide or a fumigant, as determined by the condition of the ears at time of roasting-ear harvest, Burlington County, N. J. 1941*

Material used in oi	Strength of insecticide	Long-husked variety local, white sweet corn [1]: Ears examined	Ears without live larvae	Ears with uninjured kernels	Larvae: Total	Larvae: Dead	Larvae dead	Short-husked variety Golden Cross Bantam [2]: Ears examined	Ears without live larvae	Ears with uninjured kernels	Larvae: Total	Larvae: Dead	Larvae dead
CONTACT INSECTICIDES—OIL PLUS PYRETHRINS													
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Number*	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Number*	*Percent*
Home mixed: 2-percent extract used	0.2	25	80.00	60.00	31	26	83.87	70	81.29	75.71	129	115	89.15
Above, plus 2 percent butyl oleate	.2	25	84.00	72.00	28	24	85.71	75	81.33	73.33	146	132	90.41
Commercial mixture A		25	88.00	80.00	31	28	90.32	71	92.96	87.32	129	124	96.12
Commercial mixture B		25	80.00	60.00	31	26	83.87	72	80.55	73.61	129	115	89.15
Commercial mixture C		25	68.00	68.00	48	40	83.33	75	86.67	81.33	124	111	89.52
Total or average		125	80.00	68.00	169	144	85.21	363	85.12	78.24	657	597	90.87
INSECTICIDES WHICH ACT AS FUMIGANTS, AT LEAST IN PART—OIL PLUS DICHLOROETHYL ETHER, DIETHYL ETHER, OR TRICHLOROMETHANE													
Dichloroethyl ether	2	25	92.00	80.00	31	29	93.55	71	77.46	71.83	142	122	85.92
Diethyl ether	3	25	52.00	64.00	25	13	52.00	74	22.97	31.08	126	48	40.00
Do	5	25	60.00	64.00	25	15	60.00	75	36.00	41.33	116	57	49.14
Trichloromethane	3	25	56.00	64.00	34	22	64.71	75	34.67	44.00	109	50	45.87
Do	5	25	80.00	80.00	28	21	75.00	74	44.59	60.81	130	80	61.54
Total or average		125	68.00	70.40	143	100	69.93	369	42.82	49.59	617	357	57.86

[1] The average extension of husks of 400 ears in 3 fields was 3.7 inches.
[2] The average husk extension of 214 ears in 1 field was 1.4 inches.

applied, an average of 10.24 percent more ears of the short-husked variety were free from kernel injury and 5.12 percent more of them were without live larvae at time of harvest than was the case with the long-husked variety. On the contrary, when oil containing a fumigant was applied, an average of 20.81 percent more ears of the long-husked variety were free from kernel injury and 25.18 percent more were without live larvae than was the case with the short-husked variety. Also an average of 5.66 percent more larvae had been killed by the oil-pyrethrum in ears of the short-husked variety than in ears of the long-husked variety, whereas an average of 12.07 percent more larvae had been killed by the oil containing a fumigant in ears of the long-husked variety than in those of the short-husked variety.

All applications of oil during 1941 were made unusually late in ear development, about a week before roasting-ear harvest. At this time larvae were beginning to reach the kernels. The data given in tables 41 and 44 indicate that the oil-pyrethrum became more thoroughly distributed, reached the kernels in a greater number of the ears, and wetted and killed the larvae in the ears of the short-husked variety in greater numbers than was the case in the ears of the long-husked variety. On the other hand, it is probable that the fumigants, being deposited nearer the tip of the husk, evaporate faster from the ears of the short-husked variety, whereas in ears of the variety having long husks, being distributed farther within the ears, their evaporation was slower, and the toxic gas consequently penetrated to and killed a larger proportion of the larvae in these ears.

The grower of sweet corn may well select the material to be used for earworm control according to the character of the husk of the variety he plants, using oil-pyrethrins if the variety normally has relatively short husks, and oil containing a fumigant if the variety normally has long husks.

It should be pointed out that the data discussed in this section bear no similarity to those considered in the preceding section. In the present discussion reference to short husks of one variety is a relative term referring to an average condition as compared with another average condition. Many of the Golden Cross Bantam ears examined in 1941 had relatively long husks, and most of the husks were relatively tight.

Husk Characteristics in Relation to Drought

The husks of corn ears, especially those of sweet corn, are affected in two important ways by dry weather—they become stunted and they wilt. In proportion to the severity of the drought, the husks are shorter and the modified leaves of which they are composed become limp, press less tightly about the interior silks or the kernels, and cling less tightly to one another than is the case under normal conditions. Proportionate to the adverse effect of dry weather, earworms disperse through the interior silks of such ears more rapidly, reach the kernels sooner, and often distribute themselves to parts of the cob which they would not reach in normal ears. Under drought conditions, also, earworms increase most rapidly and often reach population levels resulting in damage of unusual severity. All these conditions affect the degree of earworm control obtainable by oiling, and under some conditions it has been impossible to protect more than a few ears by any means. Fortunately these severely unfavorable conditions do not occur often, and reasonably satisfactory protection of the ears can usually be obtained during dry periods by use of oil containing insecticides, even though it may be below the level of control obtainable when environmental conditions are more favorable for plant growth.

An example of the effect of drought on sweet-corn ears and on the effectiveness of oil applications under these conditions was studied in Seminole County, Fla., during May 1940. Although the ears in most fields of sweet-corn were affected adversely by the dry weather, some fields were irrigated by an overhead portable sprinkler system and by an underground tile system as well. Depending on when the fields were irrigated, drought injury to the ears was slight or practically nonexistent in some fields ,whereas it was medium or severe in other fields to which water had not been applied.

The rate of earworm control obtained by applications of white oil containing 3 percent of dichloroethyl ether to ears of 6 fields in which drought injury ranged from none to severe, and the location of earworms in untreated ears in the same fields at time of roasting-ear harvest, are given in table 45.

Table 45.—*Effectiveness in cornfields variously affected by drought, of white oil containing 3 percent of dichloroethyl ether applied to the ears at the rate of 0.75 ml. per ear, and location of earworms in untreated ears, Sanford, Fla., 1940*

Variety	Severity of injury by drought	Treated ears						Untreated ears				
		Ears examined	Ears found at time of roasting ear harvest				Ears with uninjured kernels	Ears examined	Larvae found in the ears	Larvae found—		
			Without live larvae		With live larvae					In the silk	On kernels of the tip	On kernels of the side and middle
			Kernels uninjured	Kernels injured	Kernels uninjured	Kernels injured						
		Number	*Number*	*Number*	*Number*	*Number*	*Percent*	*Number*	*Number*	*Percent*	*Percent*	*Percent*
Golden Cross Bantam.	None [1]	1,211	1,113	16	21	91	91.2	200	245	4.00	44.08	51.02
Do..	Slight [2]	400	332	11	1	56	83.3	150	148	.68	30.40	68.92
Do..	Medium	117	41	18	36	22	65.8	73	68	0	10.29	80.71
Do..	do..	75	40	7	11	17	68.0	122	122	0	23.77	76.23
Do..	Severe	20	6	3	1	7	50.0	21	24	0	0	100.00
Ioana..	do..	25	5	5	8	7	52.0	25	30	0	6.67	93.33

[1] Irrigated before drought injury to the ears had occurred.
[2] Irrigated after slight drought injury to the ears had occurred.

Not only was the rate of control of the earworm much less in the fields that were seriously injured by drought, but injury to the kernels of untreated ears was much more serious because larvae had been able to reach the kernels sooner and in larger numbers and were able to penetrate more often to the kernels on the middle of the cobs, owing to the shortness and limpness of the husks. Under these conditions the oil dosage did not reach all the larvae in the ears because the larvae were not held for a sufficiently long period in the silks. Although severe injury to sweet corn by drought is comparatively rare, it occurs to a variable extent in some fields every year and is largely responsible for differences in the degree of control of earworms obtained by applications of oil or oil containing insecticides to ears of the same variety grown in different seasons and localities.

EARWORM POPULATIONS AND HUSK CHARACTERISTICS

Earworm populations in the Northern States usually occur at a rate of no more than 1 or 2 per ear, even when the percentage of ears attacked approaches 100, but in the Southern States there are often 5 to 10 or more larvae per ear. When most of these survive and reach the kernels, they may devour the ears entirely (fig. 2). With higher population levels the husk character assumes proportionately greater importance. If the husks are short and loose, the larvae survive in large numbers because they reach the kernels more quickly, disperse more rapidly to different parts of the cob, and compete less with one another. Thus the injury they do and the difficulty of controlling them are proportionately greater than when the larvae are concentrated in the interior silks and compete with and attack one another. These scattered and more numerous larvae are reached and killed by the insecticide less often than is the case in ears having long, tight husks, and it is necessary that every earworm that enters an ear be killed by the treatment, regardless of the level of population, because a single survivor usually will cause damage sufficient to make the ear unmarketable.

OILING IN RELATION TO EAR TYPE

Although a dosage of 0.75 ml. of oil or oil containing an insecticide was found to be satisfactory for the ears of most varieties of sweet corn, this did not seem to be true in some cases. The husks of some varieties, such as Kancross and Suwanee Sugar, extend for much greater distances beyond the cob at time of roasting-ear harvest than with most varieties, the extension sometimes being in excess of 8 inches. In such ears the mass of interior silk is much greater, in comparison, for instance, with that of ears of Golden Cross Bantam. It is probable that in varieties of sweet corn in which the husk extension is unusually long, and which contain an unusually large mass of interior silk, especially if the silk strands are rather loosely pressed together by the husks, a dosage of 1 to 1.5 ml. of oil or oil containing insecticide may be necessary to effect a satisfactory control.

HUSK CHARACTERS FAVORABLE TO CONTROL BY OILING

The results of applying mineral oil to the ears of many varieties of sweet corn in different areas and under widely different environmental conditions and earworm populations indicate that the most desirable husk should extend beyond the tip of the cob, at time of roasting-ear harvest, for between 2 and 3 inches. The husk should be reasonably tight, that is, the husk should press the interior silk strands together sufficiently to prevent earworms from crawling between them. It should lie closely about the kernels, especially those at the side of the ears,[3] and, above all, as large a proportion of

[3] Four areas of sweet-corn ears have been recognized in these and in earlier investigations. The "tip" consists of the upper 1 inch of the cob, often bearing small kernels; the "side" consists of an area about 1 inch in length next below the tip, where the kernels are often of intermediate size; the "middle" consists of the uniformly-sized kernels of most of the cob; and the "butt" consists of the lowest inch of the cob on which unusually large kernels are sometimes found.

ears as possible should possess these husk characters uniformly. Extremely short, extremely long, and extremely loose husks are all undesirable. When grown under favorable weather conditions 50 percent or more of Golden Cross Bantam ears have satisfactory husk coverage. For the reasons discussed in a subsequent section (pp. 74–78), the ear should expose the entire silk mass within a period of a few days and should not produce a later growth of silk.

EFFECT OF INTENSITY OF INFESTATION ON DEGREE OF CONTROL

In some of the foregoing discussions it has been shown that a larger percentage of ears were protected when populations of the insect were low than when each of the ears was attacked by several larvae. Applications of oil containing diethyl ether gave approximately as good control as did oil-pyrethrins when earworms were few, but not when infestations were heavier. Table 46 shows that a very high

TABLE 46.—*Effectiveness of applications of white oil containing 0.2 percent pyrethrins to sweet-corn ears under conditions where earworms were abundant, moderately abundant, or scarce*

Rate of occurrence of earworms	Treated and check ears found to be without live larvae or with uninjured kernels at time of roasting-ear harvest					
	Checks—untreated ears			Treated ears		
	Ears examined	Ears without live larvae	Ears with uninjured kernels	Ears examined	Ears without live larvae	Ears with uninjured kernels
	Number	*Percent*	*Percent*	*Number*	*Percent*	*Percent*
Abundant [1]	50	4.0	4.0	50	66.0	72.0
Moderately abundant [2]	100	12.0	31.0	99	83.8	76.8
Scarce [3]	100	53.0	89.0	100	97.0	100.0

[1] 2 lots of Truckers' Favorite corn examined at Ocala, Fla., on June 10, 1940.
[2] 2 lots of local white sweet corn examined in Burlington County, N. J., on Sept. 22 and Oct. 4, 1940.
[3] 2 lots of Golden Cross Bantam sweet corn examined in Burlington County, N. J., and Congers, N. Y., on Oct. 1 and Sept. 19, respectively, 1940.

rate of control resulted from applications of white oil containing pyrethrins to ears of Golden Cross Bantam, under conditions of low earworm populations, but that under conditions of high earworm populations lower rates of control resulted from similar applications. The rate of control was approximately proportionate to the level of earworm populations or to the percentage of untreated ears that were infested.

The use of oil, either alone or with an insecticide, was more effective under conditions of light than under conditions of heavy earworm populations. In proportion as earworm populations are larger, however, it is increasingly desirable to use an insecticide with the oil, since a proportionately better control was obtained when the oil used contained an insecticide.

OCCURRENCE OF DEAD LARVAE IN OILED EARS

Oil containing pyrethrins kills earworms in the ears almost at once, and the dead larvae are usually found where they were feeding when the oil-insecticide reached them. When these larvae are small they are inconspicuous, but they are increasingly noticeable if they are killed as fifth or sixth instars. If their bodies rot on the tip kernels, the ear has almost as objectionable an appearance as it would have if the larvae had continued to feed in it. It is quite desirable, therefore, to apply the oil containing an insecticide while the larvae are small, or not more than half grown.

In examining sweet-corn ears to which oil containing an insecticide had been applied, much difference was observed in the condition of the dead larvae. In some ears large larvae had decomposed and discolored the surrounding silks, the ear thus presenting a very unattractive appearance; whereas in other ears the larvae had not decomposed at all between the time of treatment and harvest, a period ranging from 1 to 2 weeks, and they appeared not much different from living earworms. The extent of discoloration or decomposition of the larvae in oiled ears was often correlated with the husk character of the ears. Larvae usually became decomposed more rapidly in ears having loose husks than in those having tight husks. An oil application tends to run through loose silks, whereas in tightly packed silks it remains in a film about the silk strands, forming a condition of saturation.

The rate of rotting of larvae in the ears was evidently dependent on whether the character of the oil film allowed air to reach them. The subject was studied quite simply by dropping living larvae, as they were removed from corn ears, into small screw-cap vials filled with mineral oil or oil containing an insecticide. After a month it was found that of 50 larvae so treated 28 showed no evidence of discoloration or decomposition and 22 were somewhat discolored. Some of the larvae had floated to the top of the oil and come into contact with an air bubble in the top of the vials. Half of those that showed discoloration were so affected only at the spot where they were in contact with the air, and it was evident that decomposition was dependent on the presence of air in contact with the dead larvae.

In general, therefore, ears having comparatively long, tight husks, in the interior silk of which larvae became discolored less often after being killed by oil insecticide, presented a better appearance at time of harvest than did ears having loose husks, in the silks of which the dead larvae usually became discolored or decomposed. A sweet-corn ear, in the interior silk of which several small earworms had been killed by oil insecticides and which was discolored at time of roasting-ear harvest, is shown in figure 8, *A*. An ear in which several earworms of larger size had reached the tip kernels before they were killed is shown in figure 8, *B*. The kernels of the ear shown in figure 8, *A* were uninjured by earworms and, despite the occurrence of several larvae on the kernels of the ears shown in figure 8, *B*, injury was slight.

HUSK-BORING EARWORMS IN OILED EARS

In the Eastern States, where the writer has studied the problem, relatively few larvae of *Heliothis armigera* reach the kernels of corn ears by boring through the husk. However, under some conditions in-boring larvae are numerous enough to cause losses. Examination of thousands of ears and observation of larval habits have shown that the prevalence of in-boring larvae is dependent on the number of larvae that migrate from one ear to another, and the prevalence of migrants is usually correlated with populations of larvae per ear and the degree of competition in the interior silks. When there are not more than 1 or 2 larvae per ear, little competition occurs, and the larvae usually remain in the ear they originally entered until they are full grown; but with populations of from 5 to 20 individuals per ear, competition increases, some devour one another, and some leave the ear to seek more favorable feeding situations.

FIGURE 8.—A. An ear of sweet corn to which oil-pyrethrins had been applied, showing several dead larvae in the silk at time of roasting-ear harvest. No larvae had reached the kernels of this ear; B. Ear of sweet corn to which oil-pyrethrins had been applied about a week before time of harvest, showing the occurrence of dead earworms on the kernels where they were feeding at the time of oil application. Serious damage had not been done to the kernels because the larvae were not of large size when killed. New Jersey, 1941.

Since competition between larvae in the interior silks increases in proportion as they are larger, most migrants are fourth, fifth, or sixth instars. Competition increases also in proportion as the husks are wrapped more tightly about the interior silks and the larvae can disperse only by eating their way into different parts of the ears. For example, the largest number of migrants ever seen was observed in a field of Cuban Yellow Flint field corn in Seminole County, Fla., in June 1940. The husks of this variety were so tight that most of the larval population had not been able to penetrate farther than from ½ to 1 inch from the husk tips by the time they were fifth or sixth instars, competition was especially keen, and migrants were present on almost every plant.

The migrating larvae prefer to enter another ear by way of the silk, probably because the silk is more tender and desirable as food, and because they can gain shelter quickly. But if a larva tries to enter several ears in succession, only to find each ear already inhabited by as many larvae as the ear it left first, it may force its way under a husk leaf, if possible, and begin to gnaw a burrow directed toward the kernels, or it may bore without husk protection. Usually these burrows through the husk are of a diameter no larger than is necessary for the larva to enter, showing that the husk is not among the preferred foods of the larvae and that it is the kernels that they seek. In-boring larvae, recognized by the presence of the entrance burrow, may reach any part of the ear from the interior silk to the butt kernels, but they usually reach the kernels of the tip or the side.

Oil or oil containing an insecticide acts as a repellent to some of the migrating larvae that seek to enter the treated ears by way of the silk, and a larger number of migrating larvae enter treated ears by boring through the husks than is usually the case with untreated ears. In March 1939 that part of the husks containing the interior silk which extended beyond the cob tip was cut from a number of treated ears and each piece was placed in a 20- by 100-mm. vial which was inverted into a plaster of paris mold. A single earworm was placed in each cage. Some of the larvae bored through the husk several times to reach the silk, each time being repelled from feeding on the silk because of the oil, especially when pyrethrum had been combined with it. Evidence of similar behavior by in-boring larvae has also been observed frequently in field-treated ears. Such individuals frequently moved farther down and bored to the kernels of the side or middle of the cob, where the insecticide had not penetrated.

That the occurrence of husk-boring earworms is more frequent in treated than in untreated ears is shown by the data in table 47, taken from examinations of treated and check ears used in oiling experiments

TABLE 47.—*Relative proportion of corn earworm larvae entering treated and untreated ears by boring through the husk, 1939*

State	Ears examined		Larvae in ears		
	Total	Entered by boring migrants	Total	Per ear	Entered by boring through husk
	Number	*Percent*	*Number*	*Number*	*Percent*
Florida:					
Treated ears	5,757	1.80	3,822	0.66	2.7
Check ears	829	1.10	2,833	3.42	.4
New Jersey:					
Treated ears	6,483	2.16	4,454	.69	3.23
Check ears	764	.79	947	1.27	.51

Although the treated ears contained only about one-fifth as many living larvae per ear as did the check ears, about 1½ times as many of them were attacked by husk-boring larvae, and nearly 7 times as many larvae had attacked them in this way. In neither State had the proportion of the ears affected by husk-boring earworms been sufficient to cause material loss.

Since migrating earworms often are repelled from entering the silks of treated ears, but bore through the husk directly to the kernels, and because larvae having such habits might be numerous when population levels are high, this difficulty could be met by applying the oil-insecticide to all ears in a field irrespective of their marketability, in order to kill as many as possible of the earworms and thus greatly reduce the number likely to migrate.

EFFECT OF INSECTICIDES ON FLAVOR OF SWEET-CORN EARS

Next in importance to its effectiveness in protecting sweet-corn ears against injury by earworms is the requirement that an insecticide leave no residue on the kernels which can be detected or objected to by consumers of green corn. Although pyrethrum extract imparts a light-brown color to white oil, it leaves no detectable residue in any part of treated ears, and most of the other chemicals which have been discussed are as colorless as the oil with which they were combined. Dichloroethyl ether could sometimes be detected by odor or taste when evaporation from the ears had been at too slow a rate to rid the ears of it by the time of roasting-ear harvest.

Although treated ears had been eaten by the writer and a few other persons since the beginning of the studies of insecticidal control of the earworm, it seemed desirable to obtain the reaction from a wider field by asking many persons to eat treated ears and report on their flavor. To this end, during the spring of 1940, 784 treated ears were distributed in 93 separate lots to 22 tasters; during the summer of 1940, 1,548 treated ears were distributed in 209 separate lots to 78 tasters; and during the spring of 1941, 626 treated ears were distributed in 65 separate lots to 32 tasters. In all, 2,958 ears were distributed in 367 different lots, or an average of 8 ears per lot, to 124 different persons.

Since an average of about 3 persons shared the eating of the ears received by each taster, at least 372 different persons ate the treated ears. The tasters ranged from corporation presidents to farm laborers, and among those who would be expected to be more critical were several chemists, 26 entomologists, several scientists in other fields, and a number of growers of sweet corn. Some tasters knew that the ears they received had been treated, whereas others did not. It was found that the sense of taste apparently varied greatly as between persons. Some tasters who ate many ears detected no residue at all, although the writer did. One chemist always recognized ears to which dichloroethyl ether had been applied, and the sincerity of his reports was tested by distribution of untreated ears among those he sampled, and on these he found no unusual flavor. Some of the scientists were somewhat more critical than were the ordinary consumers, as shown by the ratio of residue detection by them and by other persons.

A general summary of the results of tasting sweet-corn ears to which white oil containing insecticides had been applied from 1 to 2 weeks before harvest, showed that, other than for one report of residue detection on ears to which oil-trichloromethane had been applied, which the writer believes was imaginary, no residues were detected by tasters except in 13 cases on ears to which oil-dichloroethyl ether had been applied and in 2 cases in which oil-methyl isobutyl ketone had been applied.

A study of the rate of penetration of mineral oils into ears of Golden Cross Bantam sweet corn (table 17), showed that oil of 125–135 seconds viscosity reached the cobs of all ears to which it was applied, and that oil of 200–210 seconds viscosity reached the cobs of 95 percent of the ears. Almost all the oil that reaches the cobs is deposited on the top inch in ears having average husk coverage and grown under usual conditions. The insecticidal residues found usually were on this part of the cob. Since the kernels in this part of the ear usually are smaller than on other parts, and the tip often is trimmed or broken off before the roasting ears are served, the slight residues that might remain would be eliminated before the corn was eaten.

In the tests referred to in the previous paragraph residues were found on 31 lots of corn containing 8.4 percent of the ears tasted. However, since residue was often reported from only a single ear and rarely from all the ears of a lot, the actual number of ears on which residue was detected probably was between 2 and 3 percent of those eaten by tasters.

Factors Involved in Deposit and Retention of Residues of Dichloroethyl Ether

MATERIAL AND METHOD OF APPLICATION

In the spring of 1940, in Florida, residue was detectable in ears to which oil of 250–260 seconds viscosity containing 3 percent of dichloroethyl ether had been applied but not in ears to which lighter oils containing this percentage had been applied.

In the summer, in New Jersey, no residue was detected on ears receiving oil of 125–135 seconds viscosity containing 1 percent of the chemical, but was detected on some ears to which oil containing 1½ or 2 percent of the chemical had been applied, and on 10 percent of the lots of ears receiving oil containing 2½ or 3 percent of the chemical; hence, residues were detected more frequently on treated ears as the concentration of the chemical used in the oil was increased.

Residue was detected on ears to which a dosage of 1 ml. of oil of 125–135 seconds viscosity containing 3 percent of dichloroethyl ether had been applied, but none was detected on ears which received 0.50 or 0.75 ml. of this mixture.

No relation was observed between the place of liberation of dosage and the frequency of detection of residues.

TIME OF APPLICATION AND TEMPERATURE

As shown in table 48, residues were detected frequently when the periods between treatment and harvest were short, but proportionately less often as the period between application and harvest was longer.

TABLE 48.—*Frequency of detection of residue of oil containing from 1 to 3 percent of dichloroethyl ether on kernels of sweet-corn ears, in relation to length of the period between application of the insecticide and roasting-ear harvest, spring and summer, 1940*

Period between treatment and harvest (days) [1]	Lots of ears eaten by tasters	Lots in which residues were detected
	Number	*Percent*
4 to 6	7	42.9
6 to 8	25	16.0
8 to 10	120	13.3
10 to 12	77	7.8
12 to 14	37	2.7
Over 14	9	0

[1] The intervals are for full days of exactly 24 hours. A period of 6 days and 2 hours would be included in the line 6 to 8 days.

From thermograph charts for the spring and summer of 1940, made in the vicinity of the fields in which some of the experiments were placed, totals were computed of the accumulated degree-hours Fahrenheit above zero for the periods between application of insecticides and harvest of each lot of ears. These totals ranged from 6,269.1 to 23,653.7. The records for both seasons were grouped in 3 classes in which the accumulated degree-hours ranged from 6,001 to 12,000, from 12,001 to 18,000, and from 18,001 to 24,000. Of the 275 lots of ears included in table 48, 12 fell in the first class, and on 41.7 percent of these residues were detected; 178 lots fell in the second class, on 12.4 percent of which residues were detected; and 85 lots fell in the third class, on 3.5 percent of which residues were detected.

VARIETY OF CORN

Observations during the summer of 1940 indicated that residues of oil-dichloroethyl ether were more likely to be left on ears that had developed rapidly than on those of varieties which developed more slowly, and that the odor of dichloroethyl ether persisted longer in the silks of ears having tight husks than in the silks of ears having loose husks. An odor in the silks at time of harvest, however, did not imply that the kernels would be affected, for in the ears having tight husks most of the dosage remained in the silk mass and little of it reached the kernels; whereas in ears having loose husks, the dosage tended to run through the silks and be deposited on the kernels. It is probable, however, that evaporation of dichloroethyl ether from ears having loose husks was more rapid than from those having tight husks.

PROBABLE CAUSES OF RESIDUES

The reported residues of oil-dichloroethyl ether on the kernels at time of harvest probably were due to faulty application of the insecticide. When oil of 125–135 seconds viscosity containing 2 percent of dichloroethyl ether (the percentage recommended) had been applied at a dosage of 0.75 ml. per ear just after wilting of the silks, and by means of a pump oiler the spout of which was inserted into the tip of the ear for no more than ½ inch, residues were detected on very few ears, and then only by persons having an unusually keen sense of taste. When the insecticide is mixed carelessly into the oil so that a much higher concentration than 2 percent is put into the oil, and when the mixture is applied at twice the recommended dosage, or through poor timing is applied only a few days before harvest, insecticidal residues may be expected to occur on some of the treated ears. Cool, wet periods, during which dichloroethyl ether evaporates slowly, seem to be especially hazardous, but such weather does not usually persist during the entire period when ears are developing.

Successful Commercial Use

That oil-dichloroethyl ether is an effective insecticide, reasonably safe to use by growers of sweet corn, is shown by a commercial application at Vineland, N. J., during the summer of 1940. The grower who made the application produced about 12 acres of Maule's Lead All sweet corn in successive plantings, to the ears of most of which white oil of 125–135 seconds viscosity containing 2 percent of dichloroethyl ether was applied by use of pump-oilers in knapsack assembly. The entire crop, consisting of more than 60,000 ears, was marketed in the city of Vineland and was consumed locally. Although practically all the untreated ears were infested by earworms, more than 80 percent of those treated with oil-dichloroethyl ether were protected, and not a single complaint of insecticidal residue was received.

RELATION OF OILING TO POLLINATION AND KERNEL DEVELOPMENT

In the earliest studies with mineral oil it was observed that interference with pollination occurred when the oil was applied too soon after silk exposure. However, since it was generally believed that pollination occurred before the third or fourth day after silk exposure it seemed probable that this difficulty could be met by suitable timing of applications. To gain information on this point ears of Snowflake corn were oiled on the day of first silk exposure and on 9 successive days thereafter (table 49).

Table 49.—*Effect on development of kernels of Snowflake roasting-ear corn of the application of white oil of 200–210 seconds viscosity from the 1st to the 10th days after silks were exposed, Dade County, Fla., 1938*

[Oil applied March 18 to 27; ears examined March 31]

Consecutive days after silk exposure	Ears having from 25 to 75 percent of the kernels developed	Ears having from 76 to 100 percent of the kernels developed	Consecutive days after silk exposure	Ears having from 25 to 75 percent of the kernels developed	Ears having from 76 to 100 percent of the kernels developed
	Percent	*Percent*		*Percent*	*Percent*
1[1]	40	60	6	0	100
2	80	20	7	10	90
3	60	40	8	10	90
			9	30	70
			10	0	100
Average for first three days	60	40	Average for 4th to 10th day	8.6	91.4
4	0	100	Untreated ears[2]	8	92
5	10	90			

[1] 10 ears were oiled daily. The first day of record was the day on which the silk first appeared.
[2] 25 check ears were examined.

It appears that the silks had been completely pollinated before the fourth day, for ears oiled then were as perfectly fertilized as were those that received oil on any successive day. The effect of oil application before pollination was completed is shown in figure 9. An ear of Golden Giant sweet corn to which oil was applied later than the third day after silk exposure is shown in figure 10.

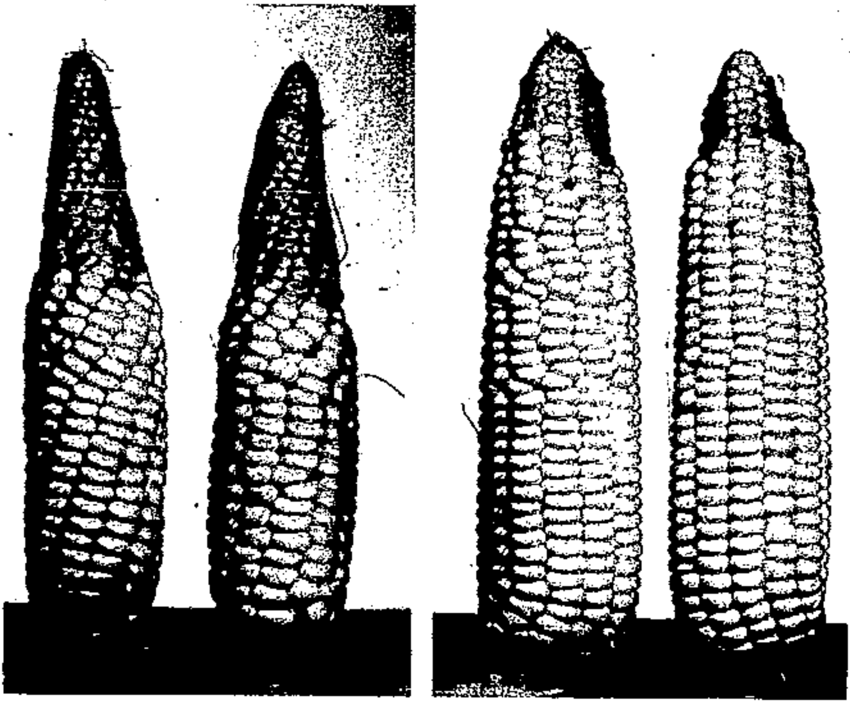

FIGURE 9.—Injury to sweet-corn ears by mineral oil applied too soon after silk exposure. The two ears to the left were oiled on about the second, and the two ears to the right were oiled on about the third day after silk exposure. Dade County, Fla., 1939.

Usually silks have become pollinated when they become wilted and appear limp, but this is not always true. In many sweet-corn ears the tip kernels ordinarily do not develop, and when oiled ears are found in this condition the first inference is that the oil or the insecticide it contains was responsible. In cases where application was premature it is true that the oil has been observed to injure some of the tip kernels or where oil-dichloroethyl ether had been applied to yellow varieties the oil has been observed to change the color of some of them. An undeveloped tip seems to be characteristic of some varieties of sweet corn, however; for example, Golden Cross Bantam. Some sweet-corn breeders believe this to be a hereditary character in some cases.

Although the writer has seen fields of sweet corn, including one of Golden Cross Bantam, in which every oiled ear was filled completely with perfectly developed kernels, and many cases of oiled ears that approached this condition, this has not usually been true. The most difficult factor involved consists of a regrowth of the cobs of sweet-corn

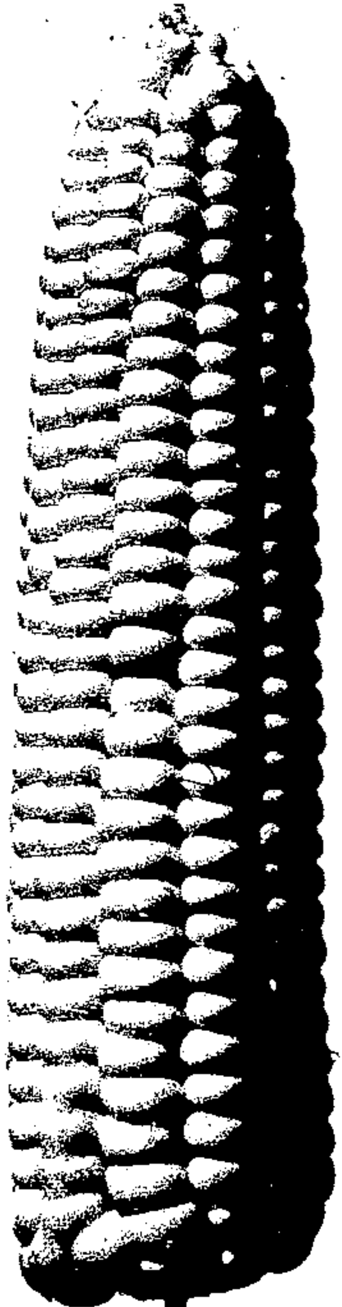

FIGURE 10.—Ear of Golden Giant sweet corn to which mineral oil was applied after the silks were wilted. This ear received little injury from the oil application and was protected against earworms. Dade County, Fla., 1939.

ears, beginning a few days, or even a week or more, after the first growth was made. This regrowth is characterized by the appearance of fresh silk at a time when the original growth has been pollinated, has wilted, or has turned completely brown. In figure 11 ears are shown in which this regrowth was considerable.

FIGURE 11.—Sweet-corn ears in which a large regrowth of the cob occurred, resulting in exposure of a large mass of new silk at a time when the first growth of silk was completely browned. New Jersey, 1941.

Sometimes, but not always, this regrowth of the cob and silk results from the stimulation afforded by rain following a period of dry weather. It seems to be more prevalent during some years than others, and in 1941 it was particularly so, being observed by the writer in Florida during May, in North Carolina during June, and in New Jersey during August and September, in each case being due, apparently, to rain following dry weather. In 1940 a field of Golden Cross Bantam corn was observed in New Jersey, to which no oil had been applied, in which this regrowth of the cob equalled in extent the first growth. By the time the second growth of silk appeared, pollen was no longer being shed, hence the cobs of many ears bore unfertilized kernels on the upper half. In this case, also, the regrowth apparently was caused by a rain after a long period of hot, dry weather. Because this condition was so prevalent during August and September 1941, all the experimental applications of oil were delayed until about a week before roasting-ear harvest—that is, the oil was applied approximately 2 weeks after silks were first exposed by the ears. Even then about 1 inch of the tip of some ears bore undeveloped kernels, but they would have been barren anyhow, even if they had not been oiled.

When silk is thus exposed during two or more periods, the application of oil insecticides after the first silk exposure seems to interfere with pollination of the silks that appear later on and often is a principal reason why oiling increases the number of undeveloped tips under some conditions. Sweet-corn varieties should be examined critically to determine those that are subject to regrowth of silk and therefore are not generally suitable for control by oiling. Studies might also be made to determine whether nutritional factors are involved and whether this condition can be corrected by improved feeding of the crop.

Since untreated sweet-corn ears often bear a small but variable portion of undeveloped tip and yet are readily marketable, it is not believed that oiled ears will be less acceptable even if, in some cases, slightly more of the tip is undeveloped. It is usually advisable to apply oil insecticides, not immediately after silk wilting, but after an interval of about 1 week after silk exposure, depending on the location of the larvae within the ears as determined by occasional examinations. Applications, however, should be made before the larvae begin to reach the kernels of many ears. Observation of the silks of a field will show whether a regrowth of silk such as has been described is taking place, and oil applications can be scheduled accordingly.

EFFECT OF OIL ON GERMINATION

In a preliminary investigation during the summer of 1941, series of ears of commercial plantings of hybrid Yellow Dent field corn, Golden Cross Bantam sweet corn, and of a seed-production planting of Yellow Country Gentleman sweet corn received applications of 0.75 ml. of oil containing insecticides applied at a time when the silks were wilted or when their tips had turned brown. The insecticides used in white oil of 125–135 seconds viscosity contained 1, 1½, 2, 2½, and 3 percent of dichloroethyl ether, and 0.2 percent of pyrethrins. In addition, a commercial oil-pyrethrum mixture was used. These ears were harvested as seed corn, about a month after the oil had been applied, and taken indoors. Germination tests were made about a month after harvest. Three ears from each treatment were selected and 10 kernels from each of three locations—the side, middle and butt of each ear—were placed in "rag-doll" germinators. For all treated ears 88.6 percent side, 95.2 percent middle, and 94.2 percent butt kernels germinated, and for the checks 99.2 percent side, 85.0 percent middle, and 92.5 percent butt kernels germinated. No significant difference appeared in the rate of germination of kernels that received applications of any of the materials mentioned, and the evidence did not show that the oil containing insecticide had affected adversely the viability of the kernels.

COMMERCIAL PRACTICABILITY OF MINERAL-OIL TREATMENT

There are several reasons why the use of the mineral-oil method of protecting sweet-corn ears against injury by earworms seems practical in the production of market or home-grown green corn. A single application suffices per ear, none of the oil or oil containing an insecticide need be lost through run-off, ears can be oiled rapidly using simple, inexpensive equipment, and the costs of labor and materials involved per acre are low as compared with the profits realized from the increased production of, and higher price obtainable for, worm-free ears.

RATE OF OILING EARS

An investigation of the rate at which oil could be applied to sweet-corn ears when a force oiler was used was made during the summer of 1938. The time consumed in treating 100 ears ranged between 2½ and 3½ minutes. Lots of 1,000 ears were oiled in an average of less than 40 minutes. At this rate oil could be applied to an acre of corn (9,000 ears per acre) in about 6 hours by a reasonably rapid worker. For most farm workers the rate would be about 1 acre a day, but this depends on the uniformity of silk exposure by the ears and the spacing of the plants. The work is slower when applications are made to ears of open-pollinated varieties that expose silks over a period of 1 or 2 weeks and in fields where ears in the proper stage of development for oiling are spread farther apart. In the case of hybrid varieties, such as Golden Cross Bantam, ears can be treated rapidly because nearly all will be ready for oiling at one time.

PERCENTAGE OF EARS READY FOR OILING AT ONE TIME

Examinations and counts in fields of Golden Cross Bantam corn have shown that where development of the plants has been uniform, as many as 80 percent of the ears may be ready for oiling at one time; that is, the silks have wilted or their tips have turned brown. The remaining 20 percent are nearly equally divided into ears with silks wholly browned that are too advanced for oiling and ears that bear fresh, unwilted silks that are too young for oiling. Under these conditions it will be more profitable to oil in one trip through the field all the ears, including those that are beyond or have not yet reached the optimum stage of growth for oiling, rather than to make a second trip to treat a remaining small number of ears. The loss from ears oiled when too young will probably be less than the cost of a second trip through the field to oil the youngest ears. Where development of the plants of hybrid varieties is not uniform, as in fields where the soil is variable, and especially in the case of open-pollinated varieties, two or more trips through a field are necessary to treat a suitably high percentage of the ears. It follows that the ears can be oiled at least cost for labor and probably with most profit to growers, if hybrid varieties whose plants develop and expose silks uniformly are selected for planting.

Cost of Oil and Insecticides

White oil of 125–135 seconds viscosity costs between 75 and 85 cents per gallon. The cost of dichloroethyl ether has been reasonable, and it can be added to oil at an expenditure of about 6 cents per gallon, when used at the rate of 2 percent by volume. Pyrethrum is more expensive, and the addition of 0.2 percent pyrethrins to oil has increased the cost by at least 40 cents per gallon. In the investigations of oil-pyrethrins it was found that although the rate of protection afforded sweet-corn ears from earworms increased in proportion as the percentage content of pyrethrins in oil ranged from 0.1 to 0.6 percent, a concentration of 0.2 percent probably was the most practical from the combined standpoint of effectiveness and cost. Data on the cost of oiling are given in table 50.

It was found that the addition of 0.1 percent of pyrethrins to oil resulted in an increase of 18.9 percent in ears protected against earworms over the rate of protection afforded by oil alone. At an increase in cost per acre of 80 cents for treatment, this gave a probable added return of $16.25 when corn sold for medium prices. Addition of 0.2 percent of pyrethrins to the oil increased the number of protected ears by 26.1 percent over that obtained by use of oil alone and, at an increase of $1.60 per acre in cost of treatment, gave a probable added return of $21.93. This rate of pyrethrin content in oil, as compared with a 0.1 percent content resulted in an increase of 7.2 percent in protected ears and, at an added cost of 80 cents for treatment, gave a probable added return of $5.68 per acre. Addition of 0.3 percent of pyrethrins to oil, as compared with 0.2 percent pyrethrin content, resulted in a further probable increased return of $1.36 per acre at medium prices.

Income Received by Growers

The practical and final test that determines whether the mineral-oil treatment for earworm control in sweet corn is commercially practical is the income received by growers for ears that have been protected and are worm-free as compared with wormy ears. Such information was obtained in Burlington County, N. J., in the summer of 1939, during the first 10 days of sweet-corn harvest. The results are summarized in table 51.

During this period, when the price of sweet corn was high, about twice as much was received for graded worm-free ears as for wormy ears. On July 6, packs of ungraded, white sweet corn were sold for from 75 cents to $1 per bushel of about 50 ears. During the first week of harvest the difference in price received for worm-free and wormy ears was about 18 cents per dozen. As sweet corn became more abundant, however, and the price declined to the level of $1 or less per bushel for the selected corn, the difference in value between

TABLE 50.—*Cost per acre of treating sweet corn with white oil containing from 0.1 to 1 percent of pyrethrins, based on the percentage of protected ears resulting from experimental oiling of ears in 7 fields of sweet corn in New Jersey during the summer of 1939*

Pyrethrins in oil (percent)	Ears protected [1]	Protected ears per acre [2]	Cost of materials per gallon: Oil [3]	Cost of materials per gallon: Pyrethrum [4]	Total cost of treatment per acre [5]	Cost of oil and pyrethrum per 100 ears: Based on number of protected ears	Cost of oil and pyrethrum per 100 ears: Based on all the ears per acre	Income per acre for green corn when price is low [6]: Protected ears selling at $1.50 per 100	Income per acre for green corn when price is low [6]: Unprotected ears selling at 75 cents per 100	Income per acre for green corn when price is low [6]: Total income	Income per acre for green corn when price is low [6]: Net value [7]	Income per acre for green corn when price is medium: Protected ears selling at at $2 per per 100	Income per acre for green corn when price is medium: Unprotected ears selling at at $1 per per 100	Income per acre for green corn when price is medium: Total income	Income per acre for green corn when price is medium: Net value
	Percent	*Number*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Untreated ears	[8] 6.4	576	None	None	None	None	None	8.64	63.18	71.82	71.82	11.52	84.24	95.76	95.76
Oil alone	[9] 57.8	5,202	0.85	None	3.95	0.033	0.019	78.03	28.48	106.52	102.57	104.04	37.98	142.02	138.07
0.1	76.7	6,903	.85	0.40	4.75	.036	.028	103.55	15.73	119.28	114.53	138.06	20.97	159.03	154.28
0.2	83.9	7,551	.85	.80	5.55	.044	.037	113.26	10.87	124.13	118.58	151.02	14.49	165.51	159.96
0.3	86.3	7,767	.85	1.20	6.35	.053	.046	116.51	9.25	125.76	119.41	155.34	12.33	167.67	161.32
0.4	86.0	7,740	.85	1.60	7.15	.063	.054	116.10	9.45	125.55	118.40	154.80	12.60	167.40	160.25
0.5	86.6	7,794	.85	2.00	7.95	.073	.063	116.91	9.05	125.96	118.01	155.88	12.06	167.94	159.99
0.6	94.0	8,460	.85	2.40	8.75	.077	.072	126.90	4.05	130.95	122.20	169.20	5.40	174.60	165.85
0.7	93.0	8,370	.85	2.80	9.55	.087	.081	125.55	4.73	130.28	120.73	167.40	6.30	173.70	164.15
0.8	92.0	8,280	.85	3.20	10.35	.098	.090	124.20	5.40	129.60	119.25	165.60	7.20	172.80	162.45
0.9	92.5	8,325	.85	3.60	11.15	.107	.099	124.88	5.06	129.94	118.70	166.50	6.75	173.25	162.10
1.0	91.7	8,253	.85	4.00	11.95	.118	.108	123.79	5.60	129.39	117.44	165.06	7.47	172.53	160.58

[1] Percentage of ears which, in experiments in 7 fields in the summer of 1939, contained no living larvae at time of harvest.
[2] Based on 9,000 ears per acre.
[3] Based on oil of 200-210 seconds viscosity.
[4] Based on 20-percent pyrethrum extract costing about $15 per pound.
[5] Includes 6 hours of labor at $3 per 8-hour day and 2 gallons of material.
[6] The average cost of production is reputed to be about $75 per acre.
[7] Total income less cost of treatment.
[8] This figure is the percentage of uninfested ears in the checks.
[9] Average of 4 white oils ranging from 125 310 seconds viscosity to ears in 7 fields of sweet corn during the summer of 1939.

TABLE 51.—*Prices received by farmers for earworm-free and for wormy yellow sweet corn at Burlington County auctions, New Jersey, 1939*

Date of sale	Worm-free ears			Wormy ears		
	Bags sold [1]	Price received by growers		Bushels sold [2]	Price received by growers	
		Per bag	Per ear		Per bushel	Per ear
	Number	*Dollars*	*Cents*	*Number*	*Dollars*	*Cents*
July 6	86	2.25	4.5	133	1.25	2.1
July 7	228	2.25	4.5	178	1.25	2.1
July 9	50	2.25	4.5	219	1.25	2.1
July 10	50	1.75	3.5	50	1.00	1.7
July 11	125	1.50	3.0	37	1.25	2.1
July 12	175	1.50	3.0	100	1.00	1.7
July 13	175	1.50	3.0	64	.60	1.0
July 14	200	1.50	3.0	60	.60	1.0
July 16	150	1.25	2.5	48	.60	1.0
Total sales or average prices received	1,239	1.70	3.4	889	1.08	1.8

[1] Bags contained 50 counted ears.
[2] Bushels contained about 60 ears but were not counted.

worm-free and wormy ears was less. This information seems to show that when sweet corn sells for higher prices, expenditures for the mineral-oil treatment would be profitable to the growers, and this was indicated further by reports from widely separated sections. It is not unlikely that if consumers could obtain worm-free sweet corn they would purchase more often, thus increasing the demand for corn. This might prevent glutting of the market, and the unprofitable prices that sometimes result.

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