STUDIES ON THE CORN EARWORM

by
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CONTENTS

Page

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PREFACE

The corn earworm as a pest of corn presents one of the most difficult problems in economic entomology today. This may be attributed to two definite causes: one, the cosmopolitan distribution of the pest, and two, the fact that its habits of feeding, especially on corn, offer it the greatest protection from parasites and insecticidal poisons.

A project was begun in Maryland in 1925 for the study of this insect under Maryland conditions. H.H.Shepard worked on this project from June 1, 1925 until June 1, 1927; from that time until June 1, 1931 the project has been carried on by the writer. Part of the results of the work between June 1, 1927 and June 1, 1929 were presented in his master's thesis in 1929. The present paper includes all the work done by the writer during his entire four years on the project.

This paper is divided into two parts: Part I on the biology and control of the corn earworm, and Part II on the relation of different kinds of food to certain characteristics of the stored fat, with regard to the possible effect on successful hibernation.

PART I

BIOLOGY AND CONTROL OF THE CORN EARWORM

INTRODUCTION

The corn earworm was described by Fabricius (4) in 1793 under the name of Bombyx obsoleta from specimens obtained probably from the West Indies. Early literature treats this insect from a taxonomic aspect. Little work was done on its biology and control before 1850. During the latter half of the ninteenth century many papers appeared on this insect, by C.V.Riley (34, 35, 36, 37), T.Glover (9, 10, 11), J.A.Lintner (14, 15, 16), G.H.French (6, 7), J.H.Comstock (2, 3), F.W.Mally (17, 18, 19), and others. The series of papers by C.V.Riley are probably the most important and show the general accumulation of knowledge of the corn earworm during this period. Quaintance (30, 31) published a series of papers on this insect between 1898 and 1905. In 1905 Quaintance and Brues (32) published a thorough and complete account of the corn earworm, which stands today as one of the most important contributions to the knowledge of this most destructive insect. More recent work that may be mentioned here are McColloch (21, 22, 23, 24, 25, 26) on oviposition and insecticidal control, Markovitch and Robert (20) on trap crops, and W.J.Philips and G.W.Barber (29) on hibernation.

IMPORTANCE

The corn earworm is rated by Hyslop (13) in 1927 as the third most important economic insect pest in the United States. It is the most destructive insect of corn in this country and as a pest of cotton is second only to the cotton boll weevil. It has been estimated by Philips (28) that 2% of the field corn crop ($2,048,134,000 in 1929) is destroyed by the corn earworm. This means a loss of over

$40,000,000. In other words, about 2,000,000 acres of field corn are grown annually to feed the corn earworm. The loss of sweet corn is much greater in proportion to the value of the crop than that of field corn. Local outbreaks often cause the loss of entire crops of beans, tomatoes, and sweet corn.

In Maryland severe damage by the corn earworm is confined to the southern and eastern parts of the state. It is normally of little consequence in the western portions and seldom if ever occurs in the highest mountainous regions.

DEVELOPMENT OF THE CORN PLANT

A complete knowledge of the development of the host plant of a given insect is perhaps as important, in many cases at least, as a knowledge of the development and behavior of the insect itself, if control measures are to be successful. Such is true particularly in the case of the corn earworm as it attacks corn. The development of the corn plant should be well understood, especially in regard to its reproductive processes.

It should be expected that the relative development of corn plants will be influenced by climatic conditions during the period of growth, the character of the soil on which it is planted, the variety of corn, and the vigor of individual plants. Some idea of the rate of development is given in Table I.

Table I. Showing the average time of appearance of stamens, ear bud, and silks after time of tasseling. Data taken from approximately 95 plants of each variety (1929).

Variety	Time of planting	Appearance of stamens after tasseling	Appearance of ear bud after tasseling	Appearance of silks after tasseling
Adams Extra Early	Middle of May	9 days	6.3 days	12.2 days
Hopeland	First of June	5.8 days	3.6 days	7 days

It is seen in this table that tassels appeared before the ear bud and that the stamens appeared before the silks. The pollen begins falling soon after the stamens appear. The pollen fall is usually heaviest in the morning after the dew has dried off the plants.

Pollen grains germinate soon after falling on the silk and the growth of the pollen tube down the silk is very rapid. Miller (27) found that pollen germinated a few hours after lodging on the silks. He further states that the pollen tubes reach the embryo sacs in the ears within 24 hours after pollination, two to four hours after which fertilization takes place.

This period of silking and pollination has had considerable influence on certain control experiments which follow. This influence is quite evident and to avoid repetition will not be discussed further here.

LIFE HISTORY

The corn earworm overwinters in the pupal stage. The adults emerge in the late spring and early summer and soon begin laying their small white eggs on such plants as will serve for food for the larvae. The larvae on hatching begin feeding on the tender portions of the plants. They mature in a short space of time, after which they burrow into the soil and construct a small cell (pupal chamber) in which pupation and transformation to the adult take place.

NUMBER OF GENERATIONS A YEAR

Under optimum conditions of temperature, food, and rainfall, the corn earworm will complete its life cycle in about 30 days, the eggs hatching in three days, the larval period lasting twelve days, and the pupal period about fourteen days. However, in Maryland conditions are such that usually not more than two broods would develop at this rate. Offspring of early emerging adults in the spring will theoretically produce three generations in a normal year and in an exceptionally long summer season a partial fourth. This would be true especially in the more southern part of the state. Passing northward and westward through the state, we find the number of broods diminishing as the seasons become shorter, until we reach the higher mountainous regions where the insect seldom if ever occurs.

The broods during the summer are not distinct. This should be expected from the long period of emergence of overwintering insects as will be shown later. Egg counts during the summer of 1928 do, however, show three more or less definite peaks (Graph I), the first from June 20 to to July 1, the second from July 20 to August 12, and the third from August 18 to September 28. The time of silking of the plants has considerable influence on the number of eggs deposited at this time and because of this factor the data lose weight in regard to distinctiveness of broods.

As far as the number of broods and the timing of such broods are concerned in regard to control, it is concluded that the generations overlap to such an extent that there is a regular and gradual building up of the corn earworm population from the beginning to the end of the season. The timing of control should be based on the development of the host plant rather than on the timing of the broods.

HIBERNATION

Attempts were made to carry corn earworm pupae through the winters of 1927-28, 1928-29, and 1929-30. During the first two years, cages were placed at Westminster, Glenburnie, and College Park, Md. All attempts were unsuccessful. The failure to get successful hibernation is attributed to the open bottom type of cage used (fig. 1).

Figure I. Showing the open bottom type of cage used for hibernation during the winters of 1927-28 and 1928-29.

During the winter of 1929-30, six special cages were used (fig. II). These cages were made in two parts, an underground part covered with ¼ inch mesh wire cloth, and an above-ground part covered with ordinary screen wire.

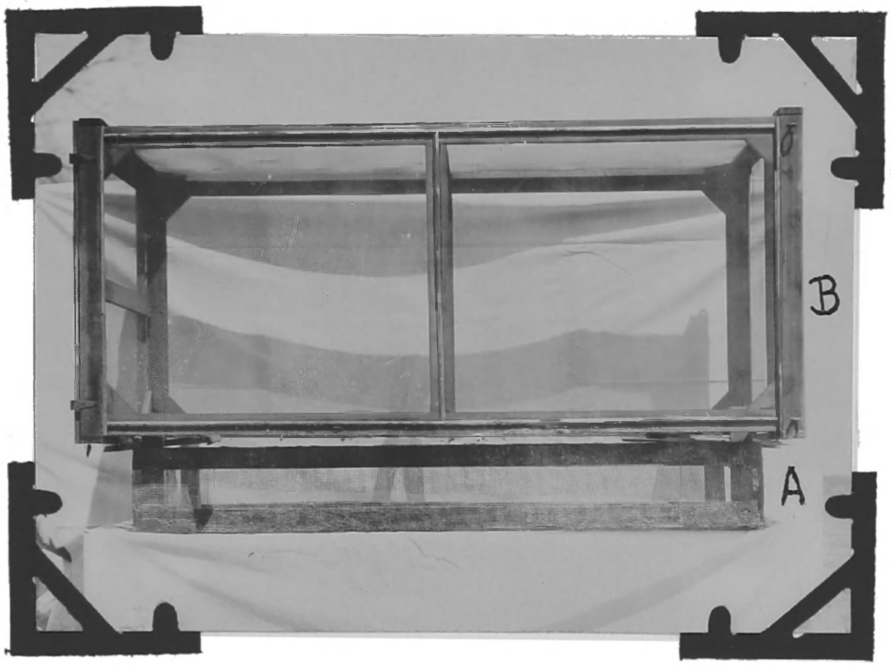


Figure II. Showing the combination type of cage used for hibernation during the winter of 1929-30. A is the underground part over which B, the above-ground part, is placed.

The bottom part of the cages was planted two or three weeks before the larvae were allowed to pupate in them. These were allowed to stand open all winter, the upper portion of the cages being placed in position early in May.

This type of cage proved successful in carrying pupae over the winter. This success is attributed largely to the protection offered the pupae from moles, which are usually abundant.

Full grown larvae were placed in cages between the dates of September 7 and September 28. Those which entered the soil between September 12 and September 22 hibernated most successfully, as shown in Table II.

Table II. Showing the effect of time of pupation on the success of hibernation (winter of 1929-30).

Cage number	No. of larvae entering soil	Date placed in cage	Date all in soil	Number emerged
1	85	Sept. 7	Sept. 11	1
2	111	Sept. 9	Sept. 19	4
3	89	Sept. 12	Sept. 22	9
4	90	Sept. 19	Sept. 28	2
5	120	Sept. 19	Sept. 28	2

Of particular interest and importance is the fact that the period of emergence occurs relatively late in the spring and continues over quite a long period of time. This is shown in Table III. The mean date of emergence was July 17.

Table III. Showing time of emergence from overwintering pupae (winter of 1929-30).

July 3-July 8	July 9-July 14	July 15-July 19	July 20-July 24	July 25-July 29	July 30-Aug. 13
3	4	2	4	1	2

On March 25, 1931, two fields were examined at Berlin, Md. for corn earworm pupae. One field had been in beans the fall preceeding and the other in tomatoes, both known to have been heavily infested with corn earworm. Five square yards of soil were screened from five different places in the bean field. An average of three live pupae were found to the square yard, which means over 14,000 live pupae per acre. Samples of soil from the tomato field yielded only approximately one-third as many pupae. Twelve live pupae were brought to the laboratory and the adults allowed to emerge. Eleven were Chloridea obsoleta; one was another species of noctuid.

Phillips and Barber (29) published an important paper on the results of eight years of work on hibernation of the corn earworm at Charlottesville and Richmond, Va.

They found a high rate of mortality at this stage: 41.8 to 43.7 percent of larvae died before pupation after entering the soil. The type of soil, depth of burrow, kind of food, and precipitation had considerable influence on the success of hibernation. Deep burrows, clay soils, or soils rich in humus, and dry weather increased the number of successfully hibernating individuals. Larval burrows are more likely to remain intact in heavy soils or soils rich in humus. Heavy rains are apparently responsible for the destruction of burrows, especially in light sandy soils. Larvae fed on corn in the late dough stage have a greater tendency to hibernate than those fed on other kinds of food. Emergence of hibernating individuals ranged from May 26 to August 24. The mean date of all years was July 8. It is interesting to note that the maximum length of hibernation was 367 days, while the minimum was 248 days.

LIFE AND HABITS OF THE ADULTS

The adults on emerging from their pupal cases immediately work their way up through the larval burrows to the surface of the soil. The wings then quickly unfold and the moths are able to fly in an hour or so.

The length of life of the adult varies with conditions of temperature and food supply. At high temperatures moths are shorter lived. Sufficient food is necessary for the normal period of adult life. Females have a tendency to be slightly longer lived than males when properly nourished. In the laboratory adults without food lived five to six days; when fed sweetened water they lived from eight to fifteen days. The length of life is increased by the cooler weather in the late summer and early fall. Quaintance and Brues (32) found a minimum length of life without food to be about four days and a maximum life period under optimum conditions to be as much as 38 days.

Egg laying usually begins three days after emergence and continues until death. The number of eggs laid by a single female varies with the individual and the conditions of her existence. The number of eggs varies from 500 to 3,000 (Quaintance and Brues (32)). Unfed females lay but few eggs. Moths feed before oviposition and continue feeding and egg laying until the end of the life period.

Moths are active at night, usually resting in some secluded place during the day. They were often observed in the curl of young plants. Flight usually begins just before dark and continues through the night. They are occasionally seen flying during the day, when they are usually feeding on flowers of such plants as may be present.

OVIPOSITION

Observations were made on oviposition during the summers of 1927, 1928, and 1929. The data of 1927 were only partially complete since the college dairy herd broke into the field and totally destroyed the crop of corn. In 1928 oviposition records were kept on three plantings of corn. Eggs were marked, numbered, and observed, and the fate of each egg determined as closely as possible. In 1929 records were kept on stalks of two plantings.

In 1928 the corn used in these experiments was of the Hopeland variety. In 1929 the first planting was what is known as Adams Early and the late planting was the same variety as was used in 1928.

Place of Oviposition

Eggs are laid any place on the corn plant where the adults can get a foothold. The fact that few eggs are laid on the under side of the leaf is due to the absence of hairs there. Eggs laid on the stalk are nearly always found along the edge or split of the sheath ("that portion of the leaf between the nodes which surrounds the culm like a split tube", Chase (1)) because this region is heavily clothed with rather long stiff hairs. When the corn is silking the silks offer unusual attraction to the corn earworm moths. The writer finds even a larger percentage laid on the silks than found by Quaintance and Brues (32) in Texas in 1904 or by McColloch (25) in Kansas in 1913-1918 (Table VII).

The distribution of 1146 eggs laid on eight stalks of the third planting, which came into silk when the population of Chloridea obsoleta was at its height is shown in Table IV. The corn was planted about July 1, 1928.

Table IV. Showing the distribution of eggs laid on eight corn plants from the time they were about one foot in height until the crop was harvested, from Aug. 20 to Sept. 28, 1928.

Stalk number	Leaves Upper surface	Leaves Lower surface	Silks	Tassel	Stalk	Ear, or Husk
51	12	0	93	31	14	6.
52	15	2	226	22	9	2
53	25	0	107	13	5	5
54	17	0	105	7	21	10
56	19	1	69	12	9	5
60	1	1	117	6	2	0
62	7	1	60	6	8	0
63	14	0	50	5	6	2
Total	110	5	827	102	74	28
Percent	9.6	.4	71.3	9.0	6.5	2.4

Oviposition records of 1929 are shown in Tables V and VI. Data for Table V were obtained from observations on an early planting of Adams Extra Early, and data in Table VI from a late planting of Hopeland variety.

Table V. Showing distribution of eggs laid on five plants of Adams Extra Early sweet corn between June 20 and Aug. 8 1929.

Stalk number	Leaves: Upper surface	Leaves: Lower surface	Silks	Tassel	Stalk	Ear, or Husk
1	3	0	8	0	0	0
2	2	2	0	2	1	0
3	2	0	2	0	0	0
4	0	1	0	0	0	0
5	1	0	13	0	0	0
Total	8	3	23	2	1	0
Percent	21.6	8.1	62.2	5.4	2.7	0

Table VI. Showing distribution of eggs laid on five plants of Hopeland between July 14 and Sept. 3, 1929.

Stalk number	Leaves: Upper surface	Leaves: Lower surface	Silks	Tassel	Stalk	Ear, or Husk
1	5	0	5	1	2	0
2	1	0	8	0	0	0
3	0	1	9	0	0	0
4	0	0	9	0	0	0
5	1	0	11	0	3	0
Total	7	1	42	1	5	0
Percent	12.5	1.8	75.0	1.8	8.9	0

These observations show that a large percentage of the eggs are laid on the silk, indicating that these are the source of the major portion of the larval population in the ears. However, as will be shown later, many ears may be infested before the silks appear, indicating that larvae from eggs laid on parts of the stalk other than the silks may become established in the ear.

Table VII. Showing the distribution of eggs on the corn plant as reported by Quaintance and Brues (32) and by McColloch (25) in comparison with results of this work.

Place of oviposition	Quaintance and Brues	McColloch	Ditman
Upper surface of leaf	32.3%	32.7%	9.6%
Lower surface of leaf	7.3%	9.4%	.4%
Silks	40.8%	30.6%	71.3%
Husk, or sheath	2.6%	2.6%	2.4%
Tassel	6.8%	8.9%	9.0%
Stalk	9.6%	15.8%	6.5%

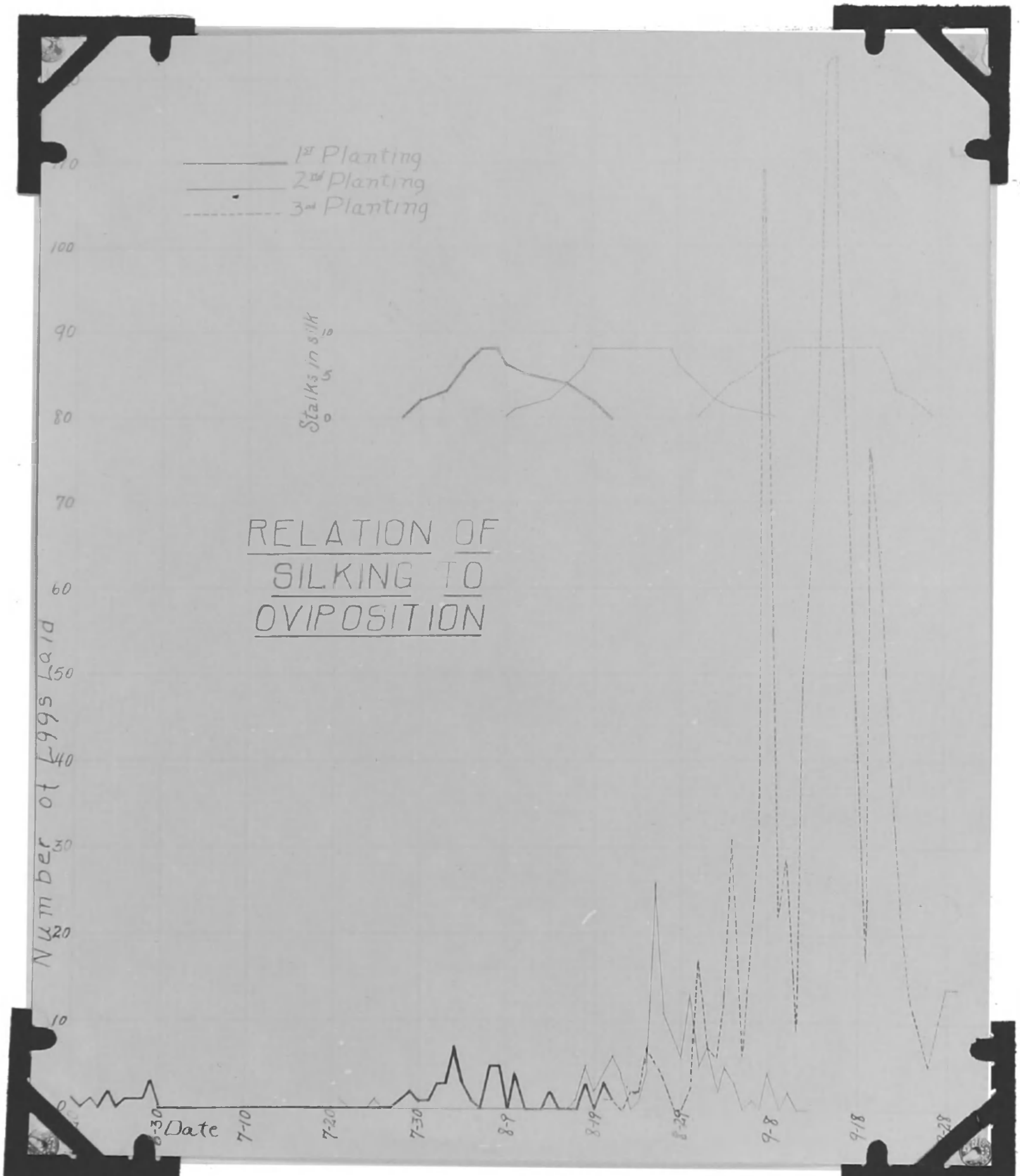
That the percentage of eggs laid on the silks found by the writer is greater than that reported by McColloch is undoubtedly due to the fact that the silking period at College Park is longer than the silking period in Kansas.

At College Park the silks of the late planting of corn remained fresh for an average of 18.3 days, varying from 14 to 22. Earlier plantings remained in silk a shorter period of time (Tables VIII and IX). McColloch states: "Under favorable conditions a plant usually remains in silk from 4 to 8 days. During years of low rainfall and hot winds fewer silks are produced and many of the silks that do appear are destroyed in 1 to 2 days by hot winds."

Table VIII. Showing the length of time silks of individual plants in three plantings remained fresh, 1928.

Time planted	Days in silk		
	Maximum	Minimum	Average
Middle of May	17	9	12.5
June first	22	12	16.25
July first	22	16	18.3

The greatest number of eggs are laid on the corn plant while it is in silk (Graph I). This fact has made it impossible to determine accurately the number of broods during a season, as already noted.



Graph I. Showing the relation between silking and oviposition during the summer of 1928.

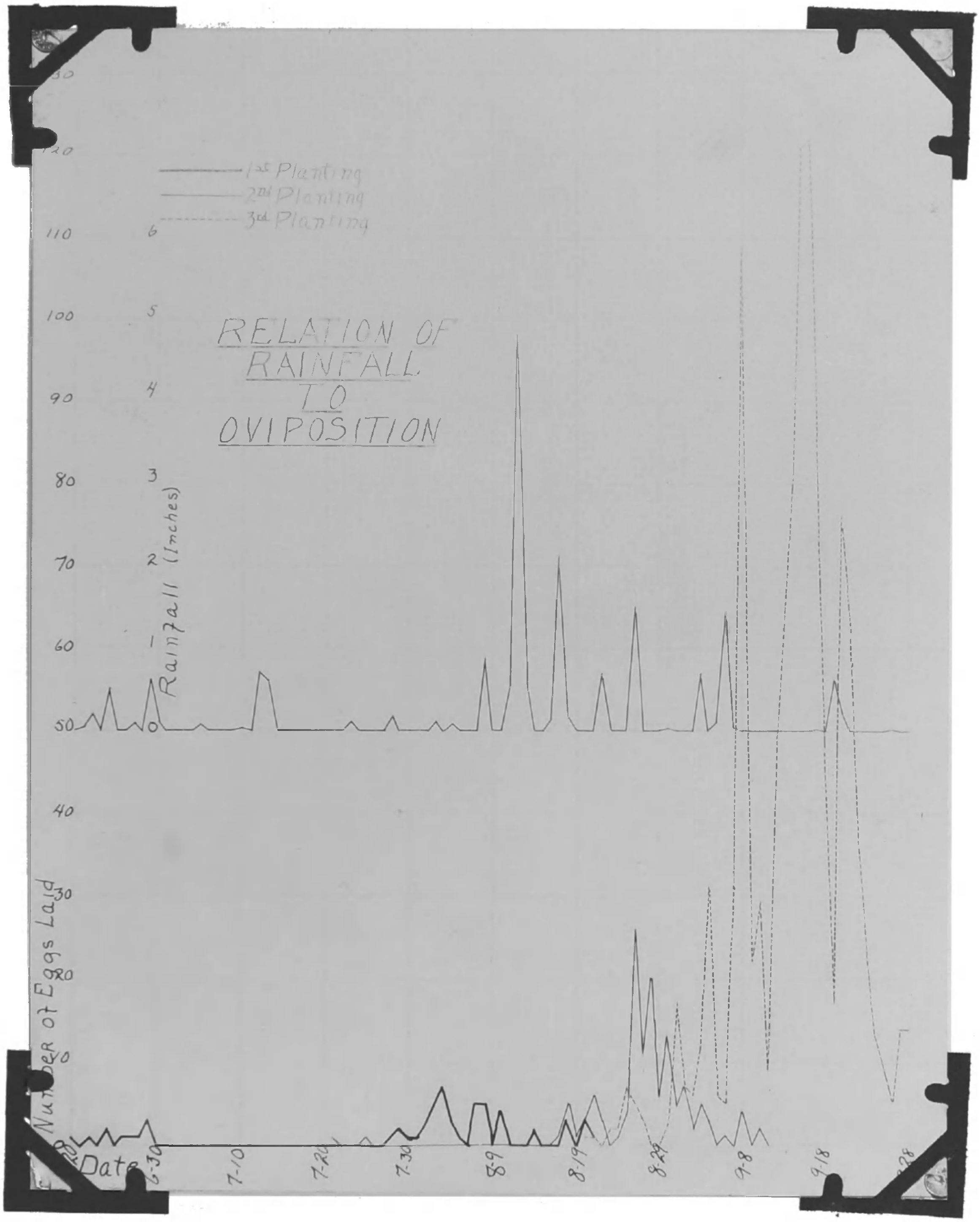
Table IX. Showing the length of silking periods for three plantings of corn, 1928.

Time planted	Length of silking period	Length of maximum silking	Date begun	Date silks are dry
Middle of May	24 days	3 days	7/29	8/21
June first	28 days	9 days	8/10	9/9
July first	26 days	10 days	9/1	9/27

Effect of Rainfall on Oviposition

Quaintance and Brues (32) state that there is a belief that after heavy rains there is an increased abundance in the corn earworm population. They advance several theories for this, among which are the softening of the soil so as to allow adults to emerge more readily, and an indirect effect in producing more abundant flowering plants which furnish nectar for the moths.

There may also be another factor of importance. During heavy rains at night it is likely that oviposition is retarded and when the weather becomes favorable for oviposition, moths have large quantities of eggs stored up in the ovaries



Graph II. Showing the relation between rainfall and oviposition during the summer of 1928.

so that a larger number of eggs are laid. An attempt was made to show the effect of rains on daily egg laying. This is shown in Graph II. These data indicate a relationship.

However, the work of Phillips and Barber (29) on hibernation shows conclusively that moths survive to a greater extent through the pupal period during dry weather. Heavy rains during both the winter and the summer cause considerable mortality of the corn earworm in the soil. Heavy rains tend to break up the pupal burrows so that adult moths cannot reach the surface of the soil. During the four years' experience of the writer with the corn earworm, the infestation was worst during the exceptionally dry, hot season of 1930. Insects overwintered successfully and the dry hot weather accelerated greatly the development through the summer.

Length of Egg Stage

The time of hatching was observed and recorded on a considerable number of eggs in the field throughout the summer of 1928. From June 20 to August 30, the egg stage varied from three to four days, most of the eggs hatching in three days. On August 30 the temperature began to drop and remained lower than usual for about eight days. It then became quite warm for about a week, September 9 to September 17, after which the temperature dropped again. With the first drop in temperature the length of the egg stage increased: eggs laid on September 3 and 4 hatched in an average of eight days. As the temperature increased again the incubation period became shorter: eggs laid on September 11 to 14 averaged four days in hatching. On September 17 the temperature dropped again and the egg stage increased to much greater length than before.

Mortality in the Egg Stage

In the oviposition studies of 1928 daily counts were made. A number of eggs were marked and watched to determine the percentage that hatched and the percentage that were infertile or parasitized. Marking of eggs on leaves and stalk was quite simple. Tags were made of small pieces of paper, numbered, and attached with short pieces of light wire. Marking of eggs on silks was more difficult.

Small paper tags were folded over the silk close to the eggs and were stuck together with a small amount of Canada balsam. Balsam is preferable to ordinary glue as it does not soften during rains.

Not all the eggs found on the plants examined were marked. On days of heavy oviposition on the silks it would have been very difficult to mark all the eggs and examine them daily without knocking a large percentage of them off. As many as 45 eggs were laid on the silk of a single ear in a day.

During the summer, from June 20 to September 28 a total of 936 eggs were marked on 48 stalks. Of these, 326 were unaccounted for, 326 hatched, 239 were destroyed by unknown parasites and predators, 33 were destroyed by Trichogramma, and twelve were infertile (Table X).

The eggs that hatched could be easily determined. They first show a faint red ring around the middle, the ring or band becomes darker and heavier, finally the egg becomes grayish. For a short time before hatching, a large dark spot appears near the top of the egg, the spot being the head of the embryo. Egg shells remaining after hatching may show a large irregular hole through which the larva has emerged, but usually the larva after emerging eats a part or nearly all of the remaining shell. Infertile eggs are also easily determined. They never show the red ring, but remain white; they soon become conical and finally shrivel up.

Table X. Showing the fate of eggs of the corn earworm on the corn plant, 1928.

Fate of eggs	First planting		Second planting		Third planting		Total	
Total number of eggs marked	90	100.0%	156	100.0%	690	100.0%	936	100.0%
Unaccounted for	26	28.1%	17	10.9%	283	41.0%	326	34.8%
Hatched	46	51.1%	89	57.0%	191	27.6%	326	34.8%
Destroyed by undetermined parasites and predators	16	17.7%	43	27.5%	180	26.0%	239	25.5%
Destroyed by *Trichogramma*	0	0.0%	3	1.9%	30	4.3%	33	3.5%
Infertile	2	2.2%	4	2.5%	6	0.8%	12	1.2%

Eggs parasitized by *Trichogramma* quickly become quite dark and remain so until the parasite emerges.

Eggs destroyed by undetermined parasites and predators vary somewhat in appearance. The contents of the egg have been sucked or squeezed out leaving the egg in a more or less irregularly collapsed mass. In the laboratory this kind of feeding was done by the ladybird beetle Megilla maculata DeG., and by the larva of the lacewing fly Chrysopa occulata Say. It is possible that the feeding of other predators may be similar.

The large percentage of eggs unaccounted for is due to several factors. First, severe winds and rain may have dislodged a portion. Second, insects feeding on the silks cut the silks from the ear. The spotted cucumber beetle, Diabrotica 12-punctata, fed considerably on the silks of corn during the summer. Earworm larvae feeding in the tips of the ears often cut away the entire silks. The silks may then fall to the ground or be blown away by the wind. Third, predators may have eaten the entire egg or at least loosened the shell so that it all fell off. Fourth, eggs, especially those on the silks, may have been knocked off during daily examination. Fifth, birds may have been responsible for the disappearance of some.

In view of these facts, it seems logical that a more nearly correct conception of the percentages of hatch, parasitism, and infertility may be arrived at if the eggs which have been marked unaccounted for be eliminated, as in Table XI.

Table XI. Showing percentages of hatch, parasitism by Trichogramma, destruction by undetermined parasites and predators, and infertility of all eggs accounted for, 1928.

Fate of eggs	First planting		Second planting		Third planting		Total	
Total eggs accounted for	64	100.0%	139	100.0%	407	100.0%	610	100.0%
Hatched	46	71.8%	89	64.0%	191	46.9%	326	53.4%
Destroyed by undetermined parasites and predators	16	25.0%	43	30.9%	180	44.2%	239	39.1%
Destroyed by Trichogramma	0	0.0%	3	2.1%	30	7.3%	33	5.4%
Infertile	2	3.1%	5	2.6%	6	1.4%	12	1.9%

It is interesting to note that only about one-half the eggs under observation hatched during the season, and that the mortality during the egg stage increased as the season advanced. It would have been still more interesting if the mortality could have been determined in the larval stage. However, attempts to do so were unsuccessful, for, once the husk was interfered with, the natural development of the worm was interrupted. Also, once the husk was disturbed, opportunity was offered for birds to feed upon the ear. Birds were particularly numerous in the corn field during the summer of 1928 and caused considerable damage to the corn.

LIFE AND HABITS OF THE LARVA

After a review of the literature on the corn earworm, it seemed possible that a thorough knowledge of oviposition might open some avenue of attack on this insect. With this end in view considerable effort was expended in studying oviposition habits. Control experiments were designed and carried out only to reveal that a close study and observation of the larval stage would be necessary before attaining the end in mind. The failure of oviposition studies to provide some vulnerable spot at which successful control could be obtained has in the writer's mind increased greatly the importance of investigation of larval life and habits.

Food Plants

The species of plants attacked by the larvae are almost unlimited. Quaintance and Brues (32) give a rather extensive list of food plants reported up to 1905. The author has compiled what is believed to be a complete list of cultivated host plants up to date (Table XII). This includes 18 plant families. However, corn is the preferred food, cotton second choice, and tomatoes and beans are also severely damaged at times. In Maryland, where cotton is not a commercial crop, corn, beans, and tomatoes are attacked.

Table XII. A List of cultivated plants attacked by *Chloridea obsoleta*.

Family	Common name	Specific name	Where reported
Gramineae:	Corn	*Zea mays* L.	N.&S. America, Africa, Australia, etc.
	Sorghum	*Holcus sorghum* L.	N. America
	Millet	*Chaetochloa italica* (L.) Scribn.	Africa
	Sugar cane	*Saccharum officinarum* L.	N. America
	Wheat	*Triticum aestivum* L.	Australia
	Oats	*Avena sativa* L.	Australia

Table XII. (continued)

Family	Common name	Specific name	Where reported
Gramineae:	Barley	Hordeum vulgare L.	Australia
	Rice	Oryza sativa L.	India
	Broom corn	Holcus sorghum var. technicus Bailey	Africa
	Kaffir corn	Holcus sorghum var. caffrorum Bailey	N. America
Leguminosae:	Alfalfa	Medicago sativa L.	N.& S. America, Europe, Africa
	Chick pea, or Gram	Cicer arietinum L.	Europe, India, Africa, Asia, Mexico
	Beans, Lima and String	Phaseolus spp.	N.&S. America, Europe, Africa
	Pea	Pisum sativum L.	N.&S. America, Africa
	Sweet pea	Lathyrus odoratus L.	Africa
	Khesari	Lathyrus sativa L.	India
	Lablab, or Hyacinth bean	Dolichos Lablab L.	India
	Cowpea	Vigna sinensis Endl.	N. America
	Soybean	Glycine hispida	N. America
	Vetch	Vicia vilbosa Roth	N. America
	Pigeon pea	Cajanus indicus Spreng	Tanganyika Terr.

Table XII. (continued)

Family	Common name	Specific name	Where reported
Legum-inosae:	Red clover	Trifolium pratense L.	New Zealand
	Peanut	Arachis hypogaea L.	Australia
Solan-aceae:	Tomato	Lycopersicon esculentum Mill.	N.&S. America, Europe, Africa, etc.
	Tobacco	Nicotiana tabacum L.	N.&S. America, Europe, Africa, etc.
	Pepper	Capsicum tuberosum L.	N. America
	Ground cherry	Physalis sp.	N. America
	Egg plant	Solanum melongena L. var. esculentum	N. America
	Potato	Solanum tuberosa L.	N. America
	Capegoose berry	Physalis peruviana L.	Africa
Rosa-ceae:	Peach	Prunus persica Seib. & Zucc.	N. America, Africa
	Plum	Prunus domestica	N. America, Africa
	Pear	Pyrus communis L.	N. America
	Strawberry	Fragaria sp.	N. America
	Rose	Rosa sp.	N. America
	Apple	Pyrus malus L.	Africa

Table XII. (continued)

Family	Common name	Specific name	Where reported
Crucif-erae:	Cabbage	Brassica oleracea var. capitata L.	N. America, Africa
	Collards	Brassica oleracea var.	N. America
	Rape	Brassica napus L.	Kenya Colony
	Cauliflower	Brassica oleracea var. botrytis L.	Africa
	Radish	Raphanus sativus L.	Africa
	Turnip	Brassica Rapa L.	Africa
Caryo-phylla-ceae:	Carnation	Dianthus caryophyllus Sm.	Cape Colony
Resed-aceae:	Mignonette	Reseda sp.	Europe
Lilia-ceae:	Asparagus	Asparagus officinalis L. var. altilis L.	N. America
Gerani-aceae:	Geranium	Geranium sp.	N. America
Irid-aceae:	Gladiolus	Gladiolus sp.	N. America
Mor-aceae:	Fig	Ficus carica L.	N. America
	Hemp	Cannabis sativa L.	N. America, Europe, India

Table XII. (concluded)

Family	Common name	Specific name	Where reported
Vitaceae:	Grape	Vitis sp.	N. America
Malvaceae:	Cotton	Gossypium sp.	N. America, India, Africa, etc.
	Okra	Hibiscus esculentis L.	N. America
	Hollyhock	Althaea rosea Cav.	N. America (?)
Cannaceae:	Canna	Canna indica L.	N. America
Compositae:	Sunflower	Helianthus annuus L.	India, Africa, N. America
	Dahlia	Dahlia sp.	N. America
Cucurbitaceae:	Squash	Cucurbita pepo var. condensa Bailey	N. America
	Pumpkin	Cucurbita pepo L.	N. America
	Cucumber	Cucumis sativus L.	N. America
	Muskmelon	Cucumis melo L.	N. America
	Watermelon	Citrullus vulgaris Schrad.	N. America
Convolvulaceae:	Sweet potato	Ipomoea Batatas Lam.	Africa
Linaceae:	Flax	Linum usitatissimum L.	India (?)
Rutaceae:	Orange, etc.	Citrus spp.	Africa

Habits of Young Larvae

Young larvae were observed both in the laboratory and in the field on young corn plants and on the silks.

Immediately after hatching, the young larvae begin eating the empty egg shell: sometimes only a little is eaten, while at other times nearly the entire shell is devoured. After satisfying themselves with the shell, they begin searching for other suitable food. They crawl slowly over the plant stopping now and then and raising their heads apparently to look about. As they crawl, they bite at the leaf surface from time to time. As with most young lepidopterous larvae they spin a web-like thread on the surface along which they are crawling. If they happen to lose footing, this helps to keep them from falling from the plant.

The first observations on young larvae were made on young corn plants. Here the young larvae wandered about aimlessly over the corn plant searching for a suitable place to feed. They seemed unable to feed on the larger outer leaves, but apparently could succeed on the younger tender leaves of the curl. The difficulty seems to be in reaching this young and tender part of the stalk. If the larva falls from the leaf it has difficulty getting up the slender thread back to the leaf again. When the wind is blowing, it is almost impossible for the larva to crawl about the plant; many are blown to the ground. When the soil is dry and powdery, the larva has but small chance of reaching another corn plant. However, when weeds are abundant it may feed on these until it gains sufficient size and strength to crawl back to the corn plant. In the laboratory larvae were found to be able to live on *Solanum carolinense* L., *Ambrosia artemisiifolia* L., *Bidens bipinnata* L., and *Portulaca oleracea* L., which were found as weeds in the corn field, and they are known to live on many other such common weeds as *Chenopodium alba* L. and *Amaranthus* sp.

The writer found the time to enter the ear to vary from one-half hour to over two and one-half hours both in the laboratory and in the field. In the field the larvae observed were from eggs which hatched on the silk. In the laboratory newly hatched larvae were placed on silks, usually midway between the tip of the ear and the end of

the silk. Both in the field and in the labora
larvae wandered more or less haphazardly until
the tip. Notes on two young larvae are given below.
These are typical of some twenty observations.

August 28: Young larva placed on silk 2:20 P.M. It immediately started crawling up the silk, but two minutes later reversed its direction. It then crawled downward, pausing twice for periods of half a minute. When it reached the bottom of the silk it stuck its head out in all directions, suddenly became oriented, and without pausing once walked straight up the silk and into the ear in about seven minutes. The whole process as recorded consumed 32 minutes.

September 22: Larva hatched at 1:16 P.M. From this time until 3:20 it was under continual observation. It wandered about the silk, now up, now down, pausing at intervals to look about but making no considerable progress. At one time, however, it was within one inch of the ear, but reversed its direction. At 3:20 it was within two inches of the bottom of the silk and headed downward, having spent over two hours in accomplishing less than nothing.

McColloch (25) states, "probably within six hours after they hatch they are down in the tip of the ear." C.H. Richardson (33) also made observations on the entering of the tip by young larvae. He states,"Experiments were made summer before last (1913) in which we found that the young worm was in the apex of the ear within twenty minutes after hatching."

An experiment was designed to determine the number of larvae entering the ear from different parts of the plant. Six cages were used, the above part of the hibernation cages already described, each being placed over an individual plant. In the first part of the experiment young larvae were used. The results are shown in Table XIII. Plants were examined several days after the larvae were placed on them.

Table XIII. Showing the effect of place of oviposition on successful entrance of the ear by young larvae placed on plant, 1929.

Where placed on plant	No. of ears on plant	No. of larvae placed on plant	No. in ear
Extreme top leaf	1	8	0
Leaf arising at base of ear	1	9	2
Leaf arising just above ear	2	10	1
Extreme bottom leaf	1	5	1
Extreme top leaf	1	9	0
Total		41	4

The second part of the experiment was somewhat different: instead of larvae, eggs were placed on the plants.

The results are shown in Table XIV. Adams Early variety was used in the first instance, while Hopeland was used in the last part.

Plants were examined for time of hatching of the eggs and again several days after hatching to determine the number of larvae in the ear.

Table XIV. Showing the effect of place of oviposition on successful entrance of the ear by young larvae hatching from eggs on the plant, 1929.

Where placed on plant	No. of ears on plant	No. of eggs placed on plant	No. of eggs hatched	No. of larvae in ears
Stalk near tassel	1	9	4	0
Second leaf from top	2	10	8	2
Tassel	1	13	7	1
Leaf arising just above ear	1	13	7	0
Stalk 8 inches above ground	1	9	4	2
Leaf below ear	1	11	7	0
Total		65	37	5

These experiments were not extensive enough to permit definite conclusions to be drawn. They do, however, confirm the high rate of mortality of larvae; only 11.5% reached the ears.

From the data in Table XIII it appears that larvae hatching near the ear or below it on the plant have a better chance of reaching the silk. This should be so as young larvae are negatively geotropic and always have a strong tendency to climb upward. It may be added that they are also positively phototropic, and from their desire to crawl deep among the silks are positively thigmatropic.

In the laboratory newly hatched larvae were placed on fresh silks and watched under the binocular to determine if any feeding was done. The young larvae were observed to eat the hairs of the silks, and they sometimes attempted to eat the silks themselves. However, feeding was not extensive on the loose silks: not until the larvae have reached a point where the silks are compact and close together do they settle down and eat in earnest. Most of the larvae on reaching the silks of the tip continue eating straight down into the ear; some, however, are contented with the silk as food and mature before reaching the grains.

Larvae were also observed under the binocular to determine if feeding took place on dusted silks. So far as could be ascertained young larvae did not attempt to feed on silks which had been dusted. Dust particles clung to the hairs on the body and about the mouth. The thin web which they spin and partially drag along behind them became covered with dust particles. Crawling in the dusted silks appeared difficult. The dust prevented proper traction, and particles clinging to the hairs over the body and the thin web seemed to help in retarding the earworms. This observation indicates that a heavy barrier of dust should give protection to the ear. This appeared to be true as will be shown later where a slight reduction of infestation was accomplished by means of powdered talc.

Habits of Older Larvae

It has been said that once the larvae get into the tip they do not leave the ear until fully developed and ready for pupation. This is true to a large extent, but some larvae do leave perfectly satisfactory feeding places to hunt others. Freeborn and Wymore (5) state, "although the corn earworm spends its larval life above ground it is, after all, a cutworm in which the migratory habit is so impressed that it leaves perfectly satisfactory feeding grounds to venture to other ears during the night." The migration of earworms is more apparent during heavy infestations. Partly grown larvae have often been observed crawling over the corn plants during the day.

When the worms are fully developed they leave the ears either by cutting a hole through the husks or by crawling out the tip. More probably drop to the ground than crawl down the stalk; larvae have been observed to reach the ground by both methods. Some crawl down the stalk, feeding on the anthers which have fallen in the axils of the leaves and sometimes on the ligule of the leaves. This is especially true of larvae which leave the ears before their appetite has entirely left them. Larvae which have eaten all they desire before leaving the ear apparently are in a greater hurry to enter the soil. After they reach the top of the soil they immediately begin searching for a suitable spot to enter.

Time of Infestation of Ears in Regard to Time of Silking

Because of failure of insecticides to give satisfactory reduction of infestation, it was thought that the time of infestation might play some part. It was decided to check up on the time of infestation of the ears. In the second planting of corn, 1930, a number of ears were examined at various stages of development to determine the infestation. A number of ears were tagged and numbered, the dates of silking recorded. These ears were examined at three-day intervals, or, rather, a certain number were examined at three-day intervals. Young shoots and ears examined on the first day of silking were not tagged. The results of these observations are given in Table XV. It should be added here that the percentage of those ears infested through the tip of silk does not include those which were also infested through the husk: ears infested through the husk which were also infested through the tip are recorded only in the husk-infested group.

These observations revealed some rather startling results: first, that a large percentage of ears are

Table XV. Showing the time of infestation of ears in relation to time of silking, second planting 1930, Hopeland.

Time examined	No. of ears	% infested	% not infested	Infested through husk	Infested through tip or silk
Young ears before silking	72	55.5	44.5	44.4	11.1
Ear bud just silking	89	52.8	47.2	35.5	17.3
Three days after silking	85	81.0	19.0	35.4	44.6
Six days after silking	81	95.4	4.6	38.6	56.8
Nine days after silking	81	97.6	2.4	38.8	58.8
Twelve days after silking	92	100.0	0.0	55.5	44.5
Fifteen days after silking	85	100.0	0.0	53.0	47.0

infested before silking and second, that a large percentage of ears are infested by young larvae eating their way through the tender husks rather than entering by way of the silks. These two facts should explain partly the poor control by stomach poisons dusted or sprayed on the silks; they also may have considerable influence on the breeding of resistant varieties of corn.

It should be added that the infestations were with few exceptions by very young worms. Their entrance holes through the husks can be seen in figures III and IV.

Mortality in the Larval Stage

As in the egg and pupal stages, the larval stage is marked with heavy mortality. The mortality is heavier in heavy infestations than when the population is small.

The cannibalistic habit of corn earworms is responsible for considerable reduction in the numbers of older larvae. Newly hatched larvae, however, are not cannibalistic. Several hundred young larvae have been placed together in close quarters and no casualties occurred. But as larvae become older they develop a voracious appetite not only for their own species but for other species of caterpillars. If larvae happen to meet, they immediately attack each other and either or both are killed. If one happens to kill the other, it will immediately begin eating the dead one. This cannibalistic habit is responsible for the finding of only small numbers of larvae developing in an ear when as many as several hundred eggs may have been laid on the silk.

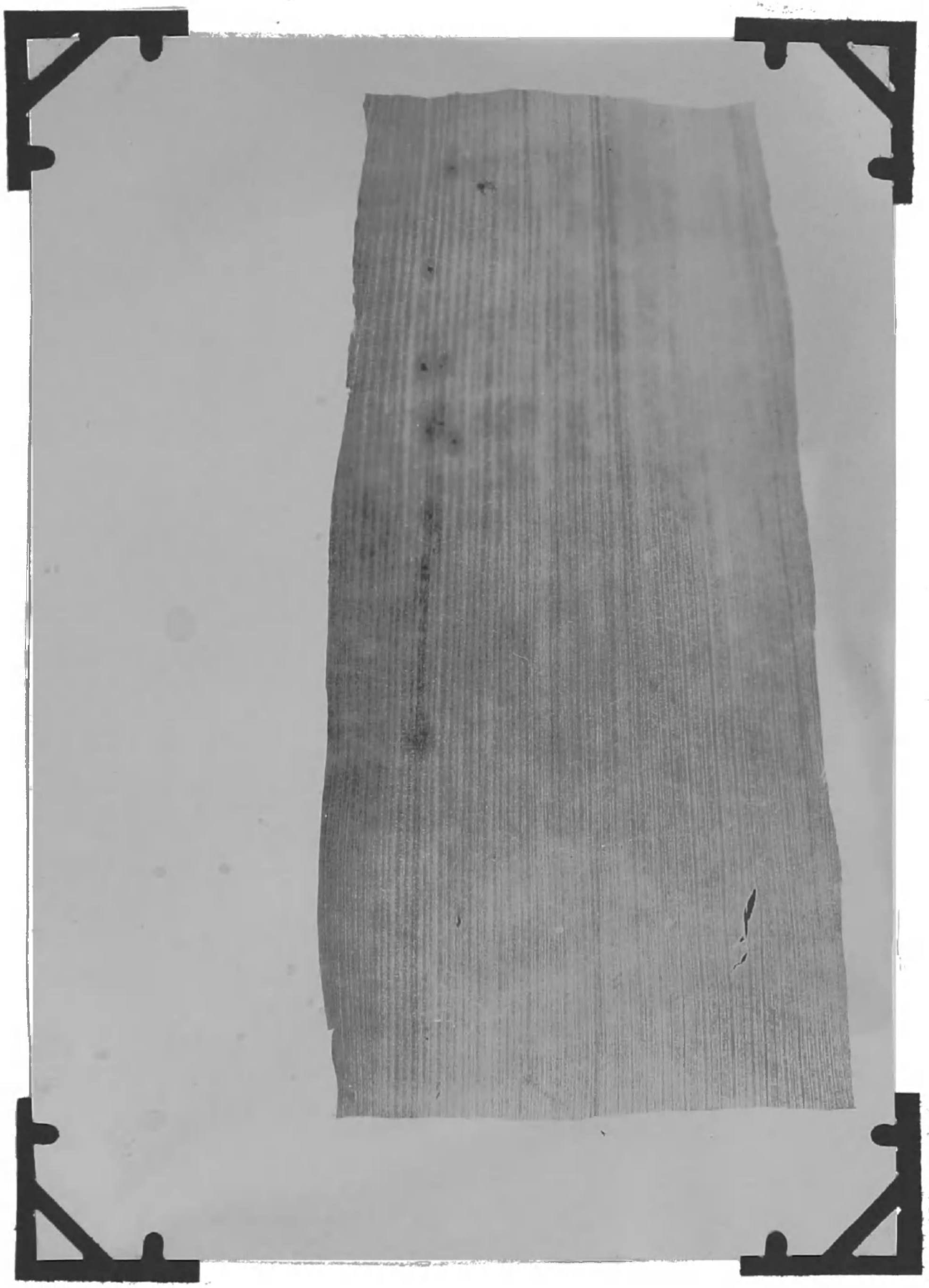


Figure III. Showing entrance holes made by very young larvae in husk of an ear that has not yet silked.
Twice natural size.

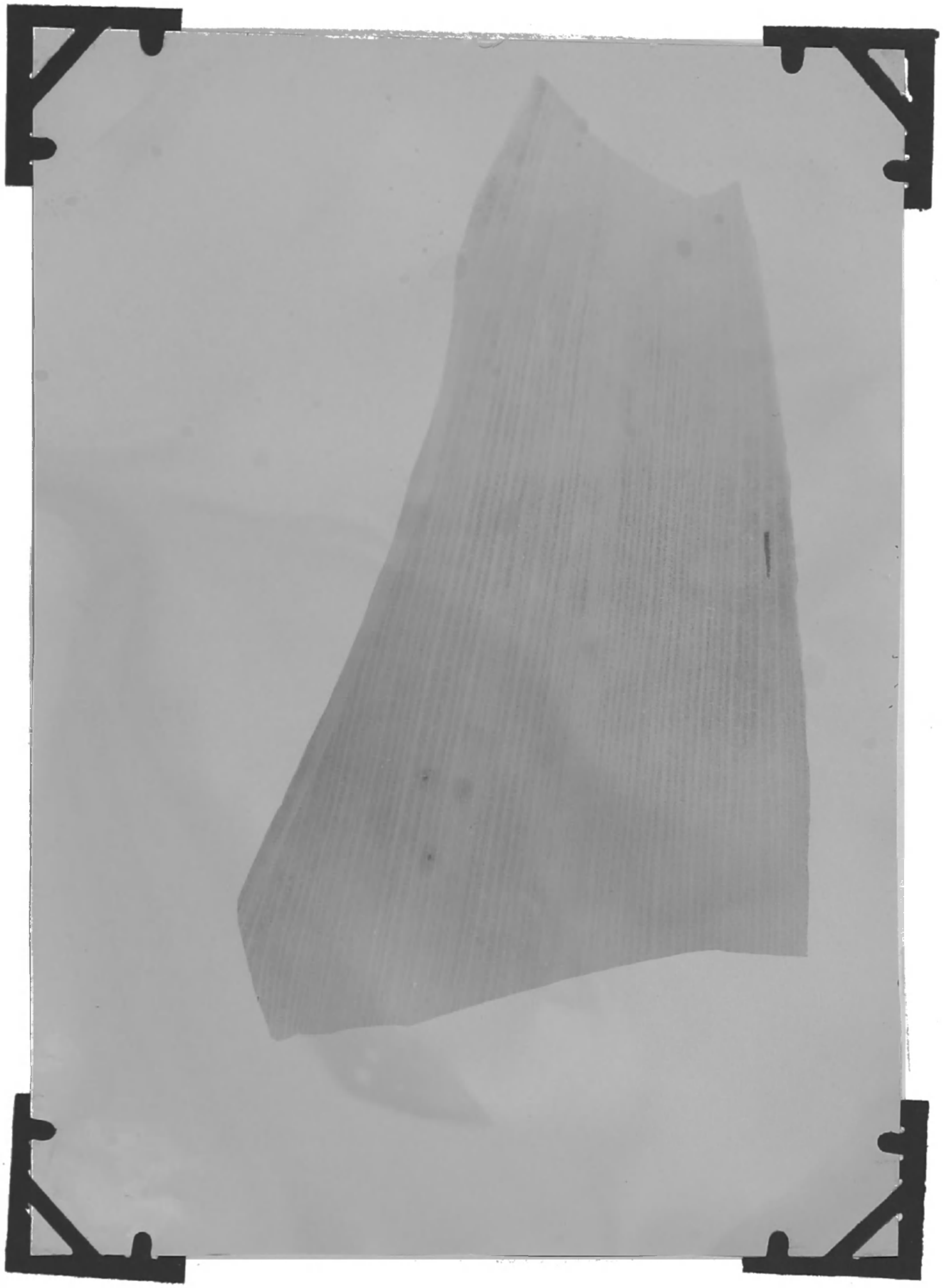


Figure IV. Showing entrance holes made by very young larvae in husk of an ear that has not yet silked.
Twice natural size.

There is a high rate of mortality of newly hatched larvae on the corn plant, especially young plants. In 1928, of 51 eggs hatching on 48 plants only two larvae succeeded in becoming established in the curl or growing bud; one of the larvae matured here while the other migrated to a young ear before maturing. In 1929 egg counts were made on corn plants up to the time of tasseling. There were 22 eggs laid on these plants, 15 of which hatched, but no larvae established themselves in the curl. The mortality of newly hatched larvae on the corn plant must be high. This is supported by the fact that there is but little curl injury except in cases of exceptionally heavy infestation.

Quaintance and Brues (32) state that the mortality of larvae on the cotton plant is also high. They state, "A number of times during the summer from 100 to 150 eggs or newly hatched larvae placed on a cotton plant have yielded only four or five larvae after a few days."

CONTROL

Natural Control

As with all other insects, there is a group of natural factors or restraints which hold the corn earworm within certain bounds. Temperature and rainfall play a great part in the occurrence and extent of population. Winter temperature and rainfall determine to a large extent the success of hibernation. Cool summers are responsible for slowing up the development of the corn earworm in all stages of development. Early cold fall weather stops development of many larvae that would under favorable conditions complete their development and hibernate. Precipitation, as shown before, influences to some extent the laying of eggs and the emergence of adults from the pupal cells. Wind no dount plays a part in the dissemination of the moths. Parasites, predators, and diseases exert considerable influence on the population of Chloridea obsoleta. Of those already reported as enemies of the corn earworm, the following were present in Maryland and will be discussed to some extent. Predators: Triphleps insidiosus Say, Nabis feris L., Chrysopa occulata Say, Megilla maculata DeG., Hippodamia convergens Guer.; parasites: Trichogramma minutum Riley; and wilt-like disease or diseases. There is also a fungus disease caused by Sorosporella uvella, which was reported in this country for the first time in 1920 by Speare (39) from specimens collected at College Park. It is primarily a disease of cutworms but has been shown to develop in Chloridea obsoleta.

Numerous species of parasites and predators of the corn earworm have been reported from nearly all parts of the world where this insect is found. They occur in greatest numbers and species in the tropics or semi-tropics: at least most of the known species have been reported from such regions. Parasites, particularly, are a more important factor in controlling the corn earworm as it feeds on host plants other than corn. On corn its habits of feeding are such as to prevent its being attacked. An incomplete list of parasites (at the present time a complete list would be impossible) is given in Table XVI to present some idea of the number of parasites of Chloridea obsoleta. These parasites, however, do not all live exclusively on the corn earworm; some or many of them have many insect hosts.

Table XVI. Showing some of the parasites of Chloridea obsoleta recorded in various countries.

Reported from	Order	Name	Attacking
U.S.	Diptera	Winthemia 4-pustulata Fab.	Larva
U.S.	"	Exorista ceratomia Coq.	Larva
U.S.	"	Euphorocera claripennis Coq.	Larva
U.S.	"	Gonia capatata DeG.	Larva
U.S.	"	Archytas peliventris	Larva
U.S.	"	Tachina (Masicera) armiger Coq.	Larva
Africa	"	Linnaemyia longirostris Macq.	Larva
Africa	"	Paratachina ingens BB.	Larva
Africa	"	Phorocera blephanda BB.	Larva
Africa	"	Sturmia laxa Curr.	Larva
Africa	"	1 Tachinid	Larva
Australia	"	2 Tachinids	Larva
Australia	"	1 Bombyliid	Larva
U.S.	Hymenoptera	Trichogramma minutum Riley	Egg
U.S.	"	Chelonus texanus	Larva

Table XVI. (concluded)

Reported from	Order	Name	Attacking
U.S.	Hymen-optera	Achaetoneura aletiae	Larva
U.S.	"	Telenomus heliothidis Ash	Egg
U.S.	"	Microplitis negripennis Ash.	Larva
U.S.	"	Perilampus hyalinus Ash	Larva
Africa	"	2 Calcids	Larva
Africa	"	1 Braconid	Larva
Australia	"	Trichogramma australicum Gir.	Egg
Australia	"	Neotelenomus sp.	Larva
Australia	"	1 Ichneumonid	Larva
Australia	"	1 Braconid	Larva
Turkestan	"	Habrobracon simonovi	Larva
Turkestan	"	Frontivia archyzsivora	Larva
India	"	Trichogramma minutum Rly.	Egg
Fifi	"	Apanteles spp.	Larva

Triphleps insidiosus though present in large numbers at times appears to be of little importance in the control of the corn earworm. Only once did the writer see *Triphleps* feeding on the field on the egg of *C. obsoleta*. Adults confined in vials with corn silks are not at all excited by the presence of corn earworm eggs, but have been observed to feed under this condition. Eggs showing typical *Triphleps* feeding were seldom found in the field. *Triphleps* will also feed on very young larvae, though it is difficult to determine the extent under field conditions. It is interesting to note that they may feed on man: the writer has been bitten many times by them.

Nabis feris has been observed in the corn field, but was never seen attacking *C. obsoleta* in any stage of its development. However, Garman and Jewett (8) state that it has proved a useful check on the corn earworm.

Two species of lady-bird beetles were found in the corn field: *Megilla maculata* DeG. and *Hippodamia convergens* Guer. They were present in all stages; toward the end of the season they became quite plentiful. The larvae feed greedily on both the eggs and larvae of the corn earworm. During the hot dry summer of 1930, adult lady-birds sought protection from the intense heat b y crawling down into the ears and could be found there in great numbers during the day.

Eggs of the lace-wing fly Chrysopa occulata were found on corn stalks at various times during the corn growing season. Larvae were also found, but were not so plentiful as those of the coccinellids discussed above. Like Megilla maculata and Hippodamia convergens, the larvae of Chrysopa occulata feed on both eggs and young larvae of the corn earworm. It is interesting to note the rapidity with which the lace-wing larva devours eggs. In the laboratory a two-thirds grown Chrysopa larva was put in a vial with C. obsoleta eggs: it immediately began feeding. The first egg was sucked completely dry in twenty-six seconds, another in 60 seconds, and two more in less than one minute each. This insect was of little importance, however, in holding the corn earworm in check, as it did not occur in sufficient numbers in the corn field.

During the season of 1928 parasitized eggs were found occasionally; as the season advanced they increased in numbers and might have been of economic importance had the season lasted longer. Specimens of the parasites were reared and proved to be Trichogramma minutum Riley.

During the past three seasons these natural insect enemies were not sufficient to bring about appreciable reduction in the number of ears infested. However, the infestation per ear was undoubtedly reduced.

The diseases that sometimes attack the corn earworm were also present throughout the entire time. On September 26, 1928, in a field of late sweet corn at Glenburnie, Md. over 400 infested ears were examined to determine the number of diseased larvae present. Of 456 larvae, 55 or 13.75% were dead of some wilt-like disease. Quaintance and Brues (32) found that 27% of larvae on cotton, 18% on corn, and 17% on alfalfa were killed by a bacterial disease in Texas in 1903 and 1904. Diseases are nearly always present among infestations of corn earworm, but usually are increased in wet weather or in wetter parts of the country.

These natural restraints play a great part in limiting the corn earworm population; however, this limit is not sufficient in many parts of the world to prevent great damage to the preferred host plant.

ATTRAHENTS AND REPELLENTS

Among the first attempts to control the corn earworm was the use of sweet baits and lights or fires. Successful use of sweets by Sorsby was reported by Glover (9) in 1854. This author in the same article recommends the lighting of fires in cotton fields, which attracted the moths and killed them. Similar recommendations are frequent in the older literature, although later investigators found both lights and sweets of little value. Quaintance and Brues (32) state, "The burning of lights in fields (cotton), the use of poisoned sweets, and the burning of sulfur were more or less practised in 1903. These and similar methods have been shown by numerous tests to be of no practical value whatever, and attention is called to their futility that needless expense may be avoided in the future."

In 1927 pails of molasses diluted 1-10 with water were placed in a small field of corn. A few moths were caught, but heavy egg laying on the corn plants continued

In the summer of 1930 several essential oils and furfural were tried as repellents on the plants during the silking period. The first planting of Golden Bantam corn was divided into plots and alternate plots designated as checks to eliminate any effect that might be caused by adjacent treatments. The results are given in Table XVII.

Furfural is soluble in water to a sufficient degree and was applied in aqueous solution. Essential oils were emulsified with potassium fish oil soap. Furfural and the essential oils were applied in solutions of about 1.5%

Quaintance and Brues report the use of various substances on the silk and ears: black pepper, tar, sulfur, tobacco, crude petroleum, pennyroyal, creolin, pyrethrum, and others. These gave negative tests as repellents against oviposition.

Table XVII. Showing the effect of de-silking alone, de-silking with application of furfural, and the effect of a few essential oils.

Plot no.	Treatment	No. ears	Percent immunity	Av. no. worms per ear
1	Check	5	25	.8
2	De-silk every day- 18 times	42	30	.7
3	Check	41	26	.7
4	De-silk every other day- 9 times	47	51	.5
5	Check	34	26	.7
6	Furfural every 2nd day (9 times), de-silk every 3rd day (6 times)	72	40	.6
7	Check	46	17	.8
8	Furfural every other day (9 times)	77	13	.9
9	Check	72	22	.8
10	Wintergreen oil every other day (9 times)	67	16	.8
11	Check	61	14	.9
12	Clove oil every 2nd day (9 times)	19	21	.9
13	Check	32	15	1.1

Note: De-silking is discussed under Miscellaneous Control Methods, p. 7[illegible].

CULTURAL CONTROL

Two methods of cultural control which have long been advised are mentioned here: late fall plowing and early planting of corn. It is a well established fact that corn which is planted early in the season is almost invariably less damaged than later planted corn. A good example of this is given by McColloch (26). From his experiments in Kansas he found that corn planted between April 15 and May 1 was least severely damaged.

Fall plowing should be of considerable help in keeping down corn earworm infestation. However, the results of this kind of control are difficult to measure. As the moths are strong flyers it would probably be useless to try this type of control on a limited scale. Unless done as a community effort, little result should be expected from the practise.

INSECTICIDAL CONTROL

Insecticide tests were conducted both in the field and in a limited way in the laboratory in regard to the control of Chloridea obsoleta on corn. These tests were conducted during the summers of 1928, 1929, and 1930. Many poisons were used, both as sprays and as dusts with different carriers and at different dilutions.

Laboratory Tests of 1928

Contact insecticides including nicotine and commercial pyrethrum sprays (Agripax, Evergreen, and Pyrethrol Soap) were tested at various dilutions on eggs of the corn earworm. Of these, none apparently had any effect on hatching (Table XVIII). These tests were begun September 20, 1928.

Table XVIII. Showing the effect of pyrethrum and nicotine on the hatching of eggs of the corn earworm.

Ovicide	Dilution	No. of eggs in test	Infertile	Parasitized	Number hatched	Percent not hatched
Pyrethrol soap	1-100	10	0	0	9	10
"	1-200	10	0	0	6	40
"	1-300	10	1	0	7	30
"	1-500	10	0	0	9	10
"	1-750	10	0	0	10	0
"	1-1000	10	0	0	9	10
Check		10	0	0	9	10

Table XVIII. (continued)

Ovicide	Dilution	No. of eggs in test	Infertile	Parasitized	Number hatched	Percent not hatched
Nicotine sulfate 40%	1-100	10	0	0	10	0
"	1-200	10	0	0	8	20
"	1-300	10	0	0	8	20
"	1-500	10	0	0	9	10
"	1-750	10	0	0	8	20
"	1-1000	10	0	0	10	0
Check		10	0	0	9	10
Agripax	1-100	10	0	0	9	10
"	1-200	10	0	0	8	20
"	1-300	10	0	0	5	50
"	1-500	10	0	0	9	10
"	1-750	10	0	0	9	10
"	1-1000	10	0	0	10	0
Check		10	0	0	9	10
Evergreen	1-100	10	0	0	9	10
"	1-200	10	0	0	8	20
"	1-300	10	0	0	7	30
"	1-500	10	0	1	8	20
"	1-750	10	0	0	7	30
"	1-1000	10	1	0	7	30

Table XVIII. (concluded)

Ovicide	Dilution	No. of eggs in test	Infertile	Parasitized	Number hatched	Percent not hatched
Check		10	0	1	7	30
Red Arrow	1-100	10	0	0	9	10
"	1-200	10	1	0	7	30
"	1-300	10	0	0	5	50
"	1-500	10	0	0	8	20
"	1-750	10	0	0	8	20
"	1-1000	10	0	0	8	20
Check		10	0	0	9	10

Several labratory tests were made during the 1928 season to determine the effect of pyrethrum dust, lead arsenate, and calcium fluosilicate on the newly hatched larva. Lead arsenate gave the most favorable results. Two of these tests are given in detail to show the effect of the poison and the bahavior of larvae on dusted silks.

Test of September 22, 1928: Three larvae were placed on fresh corn silks dusted with pure arsenate of lead. They were allowed to remain on the dusted silks for thirty minutes and were observed through the binocular during that time. The hairs on their bodies soon gathered up dust particles; their mandibles were used as an aid in crawling and soon became covered in the poison, and the little thread which was laid down or dragged along behind them gathered considerable dust. The result was that the larvae were soon unable to crawl to any extent and they aften slipped and fell from one silk to another. At no time were they observed to feed. At the end of thirty minutes they were placed on fresh clean silks although one was already writhing from the effects of the poison. At the end of 24 hours all were dead.

Test of September 23, 1928: Sixteen day-old larvae were placed on silks dusted with pure lead arsenate; after ten minutes they were transferred to fresh silks. Some showed the effect of poisoning in 15 minutes and all except one were dead in 18 hours. This one died later. Check on the above: eleven day-old larvae were placed in a vial with fresh silks. Two were dead in 24 hours.

On September first, experiments were made to show the effect of lead arsenate and calcium fluosilicate on newly hatched larvae. Ground pyrethrum heads were also used but gave no kill. Results of the lead arsenate and calcium fluosilicate are given in Table XIX. In these tests larvae were allowed to crawl through a very thin layer of dust on a piece of paper except in the thirty minute exposure to calcium fluosilicate, in which larvae were placed on dusted silks. After exposure, they were placed on clear fresh corn silks.

From these data, lead arsenate appeared to be a very efficient poison for the corn earworm. Calcium fluosilicate did not prove effective.

Table XIX. Showing effects of lead arsenate and calcium fluosilicate on young larvae in the laboratory. 1928.

No. of larvae	Insecticide used	Length of exposure	Results after 14 hours: Dead	Results after 14 hours: Partly overcome	Results after 14 hours: Alive	Results after 40 hours: Dead	Results after 40 hours: Alive	Per cent kill
21	Lead arsenate	5-8 min.	5	5	11	21	0	100
20	Lead arsenate	10-12 min.	7	6	7	20	0	100
20	Calcium fluosilicate	30 min.	1	0	19	3	17	15
21	Calcium fluosilicate	10-12 min.	6	0	15	6	15	30
20	Check		0	0	20	0	20	

During this summer insecticide tests were also carried out in the field to determine the value of calcium arsenate, calcium fluosilicate, sodium fluosilicate, lead arsenate, and pyrethrum powder against C. obsoleta on corn. The dusts were applied only on the silks and with a small hand duster.

The first series of tests were made on the first planting of corn, which began silking on the first of August. Dustings were made on the following days: Aug.4, 6, 8, 10, and 14. The ears were examined at harvesting time, that is, when the corn was in prime condition for table use. The corn was of the Hopeland variety. Results are shown in Table XX.

Table XX. Showing the effect of several insecticides on the corn earworm, first planting 1928, approximately 100 ears to the plot in results.

Insecticide	Fertilization			Burning			Infested	Not infested
	Good	Med.	Poor	None	Slight	Bad		
South check	68.0	17.2	10.9	100	0	0	89.0	10.9
Sodium fluosilicate	26.2	16.6	57.1	7.1	47.6	45.2	66.6	33.3
Calcium arsenate	50.0	39.6	10.4	8.5	46.2	45.3	67.0	33.0
Barium fluosilicate	33.9	23.7	42.3	13.5	47.4	39.0	43.2	57.5
Lead arsenate	57.3	23.5	19.1	78.0	20.6	1.4	63.2	36.8
North check	67.7	28.8	8.5	100	0	0	90.0	10.0

Note: The numbers above are percentages.

A second set of tests was made on the second planting; because of severe burning in the previous test, calcium fluosilicate was substituted for sodium fluosilicate.

Lead arsenate was tried in various concentrations with lime as the carrier. The first silk appeared about August 15 and the dusts were applied Aug. 20, 22, 24, 26, 28, and 30. Results are shown in Table XXI.

Table XXI. Showing the effect of various dusts on the corn earworm, second planting 1928, approximately 100 ears to the plot in results.

Insecticide	Burning			Worm injury			Fertilization			Not infested
	None	Little	Bad	None	Little	Bad	Good	Med.	Poor	
South check	100	0	0	26.0	41.9	32.1	71.0	6.4	22.6	0
Barium fluosilicate	0	11.4	88.6	91.4	5.7	2.8	17.1	22.8	60.0	88.6
Calcium fluosilicate	60.4	37.2	2.3	34.9	48.8	16.3	51.1	41.9	7.0	16.3
14% Lead arsenate	0	0	100	54.3	31.4	14.3	62.9	28.6	8.5	34.3
25% Lead arsenate	0	12.5	87.5	50.0	37.5	12.5	57.5	20.0	22.5	37.5
50% Lead arsenate	0	18.9	81.1	70.3	18.9	10.8	61.2	29.7	8.1	54.1
75% Lead arsenate	0	44.1	55.9	71.2	23.7	5.1	61.0	28.8	10.2	52.4
100% Lead arsenate	59.5	40.5	0	67.5	32.4	0	56.7	32.4	10.8	64.8
Calcium arsenate	1.7	45.3	52.6	78.9	19.3	1.7	52.6	26.3	21.0	61.4
North check	100	0	0	25.0	60.7	14.7	92.9	3.5	3.5	3.5

Note: The above figures are percentages

A pyrethrum dust made up of 50% ground pyrethrum flowers and 50% ground pyrethrum stems was tried on the third planting. Seven applications were given the silks, but gave no perceptible control.

Summary of 1928 Insecticide Tests

Pure lead arsenate and barium fluosilicate gave better control than the other poisons. Barium fluosilicate gave the best control but caused considerable burning and interfered with pollination. The efficiency of lead arsenate decreased as the amount of carrier increased. Pure lead arsenate gave the most promising results.

Experiments of 1929

During this summer nearly three acres of sweet corn was at the disposal of the writer and extensive tests of insecticides were made in the field. The corn was planted in sandy soil and the later plantings were hurt by the dry hot weather of that year, so that even with the larger amount of corn there was insufficient stand to make the plots as large as desired. There were, however, significant differences in the various treatments to evaluate their relative efficiencies.

A number of insecticides, both dusts and sprays, including contact poisons, stomach poisons, and non-poisonous dusts recommended for their mechanical effects were applied. Insecticidal dusts were used in various concentrations with two carriers, sulfur and talc. Hydrated lime had been used as the carrier in the 1928 tests but proved unsatisfactory because of its burning effect on foliage and silks. Talc seemed superior to either sulfur or lime in making a lighter and more fluffy mixture, which gave a better covering of the silks.

Ten applications of dust or spray were made to each plot when application were made every other day. Contact sprays such as nicotine and pyrethrum were applied at a much more concentrated dilution than generally recommended. Both dusts and sprays were applied every alternate day except in cases otherwise recorded in the table of results. The object of this application of what might be called an excess was to determine if the insecticide had any possible value in corn earworm control; if an insecticide showed any promise in concentrated form, the minimum dosage could be later determined.

Table XXII. Showing the relative effects of various dusts and sprays applied in 1929 to Hopeland sweet corn.

Material used	Burning			Fertilization			No. of ears	Per-cent clean
	None	Trace	Bad	Good	Med.	Poor		
Check	95%	5%	0%	83%	14%	3%	105	11%
Barium fluo-silicate 100%	19%	49%	32%	55%	27%	18%	113	65%
Barium fluo-silicate 75% Talc 25%	26%	53%	21%	56%	27%	17%	89	48%
Barium fluo-silicate 50% Talc 50%	40%	56%	4%	67%	17%	16%	101	49%
Talc 100% Every second day	84%	16%	0%	71%	17%	12%	106	30%
Lead arsenate 100% every second day	82%	18%	0%	92%	6%	2%	117	52%
Lead arsenate 75% Talc 25%	94%	6%	0%	84%	9%	7%	107	45%
Lead arsenate 50% Talc 50%	100%	0%	0%	83%	10%	7%	111	54%
Lead arsenate 25% Talc 75%	98%	2%	0%	63%	20%	17%	102	64%
Talc 100% Every day	100%	0%	0%	61%	18%	21%	136	38%

Table XXII. (continued)

Material used	Burning			Fertilization			No. of ears	Per-cent clean
	None	Trace	Bad	Good	Med.	Poor		
Lead arsenate 100% every third day	87%	12%	1%	84%	7%	9%	137	30%
Check	100%	0%	0%	86%	7%	7%	176	7%
Lead arsenate 100% every fourth day	98%	2%	0%	92%	5%	3%	153	27%
Lead arsenate 75% Sulfur 25%	100%	0%	0%	81%	15%	4%	90	49%
Lead arsenate 50% Sulfur 50%	99%	1%	0%	82%	12%	6%	118	50%
Lead arsenate 25% Sulfur 75%	100%	0%	0%	91%	6%	3%	137	27%
Sulfur 100%	86%	14%	0%	93%	2%	5%	140	5%
Magnesium arsenate 100%	90%	10%	0%	72%	14%	14%	126	8%
Check	99%	1%	0%	90%	7%	3%	118	8%
Magnesium arsenate 75% Talc 25%	92%	7%	1%	87%	8%	5%	155	12%
Magnesium arsenate 50% Talc 50%	97%	3%	0%	82%	7%	11%	101	12%

Table XXII. (continued)

Material used	Burning			Fertilization			No. of ears	Per-cent clean
	None	Trace	Bad	Good	Med.	Poor		
Magnesium arsenate 25% Talc 75%	98%	2%	0%	78%	17%	5%	85	15%
Magnesium arsenate 75% Sulfur 25%	94%	6%	0%	85%	8%	7%	89	29%
Magnesium arsenate 50% Sulfur 50%	97%	3%	0%	76%	17%	7%	94	18%
Magnesium arsenate 25% Sulfur 75%	67%	33%	0%	66%	27%	7%	73	10%
Check	83%	17%	0%	99%	0%	1%	84	12%
"Niagara D20"	56%	39%	5%	89%	6%	5%	131	16%
Calcium arsenate 100%	10%	58%	32%	69%	15%	16%	100	37%
"Manganar"	45%	45%	10%	69%	17%	14%	83	52%
Lead arsenate 2 lb to 50 gal trace $CuSO_4$	21%	69%	10%	88%	7%	5%	80	7%
Check	100%	0%	0%	87%	9%	4%	77	5%
Lead arsenate 1 lb to 50 gal	67%	33%	0%	89%	6%	5%	123	0%
Paris Green 1 lb to 50 gal	0%	2%	98%	73%	17%	10%	87	8%
Nicotine 1-100	17%	58%	25%	73%	3%	24%	114	3%

Table XXII. (concluded)

Material used	Burning			Fertilization			No. of ears	Per-cent clean
	None	Trace	Bad	Good	Med.	Poor		
1% sol. of Penetrol 92% Nicotine 8%	81%	19%	0%	62%	5%	33%	126	3%
Lead arsenate 2 lb to 50 gal Penetrol .5%	77%	20%	3%	84%	5%	11%	110	5%
Check	92%	8%	0%	93%	4%	3%	113	2%
"Red Arrow" 1-100	77%	33%	0%	74%	10%	16%	108	5%
"Derrisol" 1-100	25%	59%	16%	70%	7%	23%	89	5%
Paris Green 1 lb to 50 gal Hydrated lime 2 lb to 50 gal	2%	34%	64%	71%	10%	19%	101	5%
"Pulvex"	100%	0%	0%	52%	11%	37%	64	5%
Check	100%	0%	0%	75%	9%	16%	76	1%

Discussion of 1929 Insecticide Results

Lead arsenate applied every day gave the best results. As the number of applications decreased the control also decreased. Barium fluosilicate also gave comparatively good control but interfered with pollination and burnt the corn considerably. In all cases dusts were superior to sprays. In this connection it seems that the dusts kill by contact either directly or indirectly. The worms evidently do not feed on sprayed parts of the silk and it seems logical that they should not feed on dusted silk either. Observations of larvae under the binocular indicate that this is true.

There are three possible ways in which the larvae may be poisoned other than by eating food which is covered with insecticide. First, they may in crawling through the dust accumulate fine particles of it on the mouth parts: the particles may be swallowed alone or with food. This seems quite possible as the mandibles are used to some extent by young larvae as organs of locomotion. Second, dusts may cause some irritation so that the larvae in removing the irritating substance will ingest some of the poison. Third, dusts as arsenicals, may poison the young larvae directly through the cuticula.

Results of 1930 Insecticide Tests

In view of the results of observations on time of infestation of ears in regard to time of silking (see Larval Habits) of the second planting of corn in 1930, in which it was found that a comparatively large percentage of ears were infested before plants came into silk, it was decided that applications of dust from the time the ear buds appear until time of harvesting would possibly control the corn earworm. Five plots of the late planting of Hopeland variety were selected for treatment. Three plots were designated as checks and one plot to be treated with lead arsenate and another with barium fluosilicate. Barium fluosilicate and lead arsenate had given the best control of the corn earworm in the past two years and was therefore selected. The former was discontinued after two applications because of severe burning. Lead arsenate was applied at intervals of three days until the corn was to silk. After about 25% of the corn was in silk, applications were made every two days. A total of twelve applications were made over a period of 28 days. The results are given in Table XXIII.

Table XXIII. Showing the effect of lead arsenate applied to a plot of the late planting of Hopeland sweet corn 1930.

Treatment	No. of ears examined	Percent infested	Not infested
Lead arsenate	95	92.5	7.5
Check	80	100.0	0.0

Discussion of Insecticide Tests of 1930

The results of this test were rather disappointing. The results may be attributed to one of two reasons: (1) an extraordinarily heavy infestation, or (2) an inferior grade of lead arsenate. The probability is that it was due to the former reason. However, it may be said that in only one ear was it apparent that the larva had entered through the husk, all the others having entered through the heavily dusted silks.

MISCELLANEOUS CONTROL METHODS

Trap Crops

The use of trap crops has been highly recommended for many years as giving protection to tomatoes, cotton, beans, etc. The use of trap crops for cotton was first recommended by Sanderson (38) in 1858 with his belief that the corn earworm and the cotton bollworm were the same.

Corn, the favorite food of *Chloridea obsoleta*, is always recommended as the trap crop. The corn should be planted so that silking takes place during the critical period of growth of the crop to be protected, which is usually during the fruiting season. Recently, Markovitch and Robert (20) after three years' work concluded that corn did not give adequate protection to tomatoes against the corn earworm. The corn was planted in various ways among the tomatoes. It is believed by the writer that the corn used in this case only served to draw moths in greater numbers into the tomato fields. Had the trap crop been planted some distance from the tomato plot, more protection would probably have been obtained. However, Markovitch and Robert do prove conclusively that corn planted among tomatoes offers no protection to them.

De-silking and the Use of Tanglefoot

From the results of observations by the writer in 1928, by McColloch (25), and by Quaintance and Brues (32), it appeared that the bulk of infestation arose from eggs laid on the silk. With this in mind and the fact that fertilization of the ear is a rather rapid process (Miller (27)), it was decided that clipping off the silks might possibly give some control in several ways. (1) The most attractive oviposition stimulus would be removed so that there would be fewer eggs laid on the plants. (2) Larvae hatching from eggs laid on other parts of the plant would have less chance of locating the ear than those hatching from eggs laid on the silk. (3) Eggs that had been laid on the silk would be removed and destroyed.

It would seem that if the silk were cut off and a sticker such as Tanglefoot applied, entry of young larvae would be next to impossible.

In view of this reasoning a set of experiments was designed to determine the effect on fertilization and infestation of removing the silks from the ear at various intervals. The results are presented in Table XXIV.

There were several objectionable features in these treatments. First, when silks were cut off, new silk continued growing to some extent even after complete fertilization apparently had taken place; and, second, one application of sticker was not sufficient, as the husks on the outside did not grow so rapidly as those on the inside, several applications of sticker apparently being necessary

Table XXIV. Showing the effect of de-silking and the use of Tanglefoot on the tips of de-silked ears on infestation by the corn earworm, 1929.

Time of de-silking	Sticker applied	Fertilization Good	Med.	Poor	No. of ears	Percent clean ears
Every 3 days	None	81%	19%	0%	42	69%
Every 3 days	After 1st de-silking and later when needed	79%	21%	0%	39	59%
Every 3 days	When silks appeared and later when needed	80%	14%	6%	44	55%
Every 4 days	None	92%	8%	0%	39	64%
Every 4 days	After 1st de-silking and later when needed	81%	13%	6%	47	68
Every 4 days	When silks appeared and later when needed	89%	9%	2%	43	56%
Check	None				98	28%

Note: In the checks 85 to 95% of the ears were well fertilized.

to keep the tips well covered; third, the sticker is objectionable in the handling and harvesting of the ears. Outside husks must be removed before marketing.

A second experiment was devised similar to the first to determine especially the minimum time necessary for the silks to be present to insure good fertilization, and also to determine the effect of more frequent de-silkings on the infestation by C. obsoleta.

Seven plots including the checks were used. De-silkings were made at one, two, and three day intervals both with and without sticker. In the cases where sticker was used, only small amounts were applied to the tip of each ear, probably not as much as should have been used to obtain maximum efficiency. The results are shown in Table XXV.

The results of these experiments are interesting even though they indicate that the treatment is not practical. It is again evident here that the source of ear infestation is not all from eggs laid on the silks. Fertilization was incomplete to a large degree in the ears from which silks had been cut every day. This is in accordance with Miller's

Table XXV. Showing the effect of de-silking at different intervals, with and without Tanglefoot applied to tips of ears, on fertilization and infestation, 1929.

Time of de-silking	Sticker applied	Fertilization Good	Med.	Poor	No. of ears: in results	& Percent :clean ears
Every day	No	7%	17%	76%	100	87%
Every other day	No	81%	13%	6%	127	64%
Every third day	No	92%	6%	2%	91	51%
Every day	Yes	25%	22%	53%	100	63%
Every other day	Yes	83%	13%	4%	92	54%
Every third day	Yes	90%	8%	2%	89	42%
Check	No				63	42%

Note: In the check 85 to 95% of the ears were well fertilized.

work on fertilization, in which he reported that approximately 28 to 30 hours were necessary for pollination and fertilization of corn.

SUMMARY

This paper presents the results of four years' work on the biology and control of the corn earworm in Maryland.

The corn earworm was found to overwinter in the soil in the pupal stage. Emergence in cages occurred between the first of July and the middle of August.

Because of the long period of emergence of overwintering earworms broods during the summer are not distinct. Control must be based on the development of the corn plant rather than on the timing of broods.

Oviposition was found to be greatest on the corn silks, approximately 70% of the eggs being laid there.

There is considerable mortality in the egg stage: approximately only 50% of all eggs laid were found to hatch.

The time required for young larvae hatching on the silk to enter the ear was found to vary from one-half hour to over two and one-half hours.

It was found during the heavy infestation of corn earworm in 1930 that approximately 50% of young ears were in-

fested with young larvae before silking, and further that most of these infestations were by young larvae entering through the husk.

The mortality of young larvae hatching on plants before tasseling is high. Probably less than 5% of larvae hatching on young corn plants survive.

Trichogramma minutum Riley was the only insect parasite found attacking the corn earworm.

Attrahents and repellents tried proved of no value.

Lead arsenate proved to be the most efficient insecticide against the corn earworm.

Dusts were superior to sprays. Aqueous sprays of both contact and stomach poisons were of no value whatever.

De-silking of ears provided some protection from the corn earworm.

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PART II

THE RELATION OF DIFFERENT KINDS OF FOOD TO CERTAIN CHARACTERISTICS OF STORED FAT

INTRODUCTION

The investigations of the fat of insects up to the present time may be thrown into four classes: first, the amount of fat present in insects in various stages of the life cycle; second, certain physical and chemical characteristics of insect fats with identification of fatty acids present; third, the formation or source of fat in insects; and fourth, fat digestion.

In the first may be included the work of Rudolfs (16, 17) on the American tent caterpillar (*Malacosoma americana* Fabr.) and Heller (5) on the silkworm (*Bombyx mori*) and *Deilephila euphorbiae*.

The determination of physical and chemical characteristics and identification of fatty acids in insects has been carried on entirely by foreign workers. The work of Timon-David (20, 21, 22, 23) is probably outstanding. He investigated fat from a large number of insects and attempted to correlate the characteristics of the fat with the type of food eaten. Interesting is the fact that in one species of aphid he found a fat with an iodine number of 1.5. Of the series of insects with which he worked he found the iodine value to vary from 1.5 to 160.5. Huerre (9) and Liebermann (13) studied the fat of cochineal and detected oleic, linoleic, and myristic acids. Other fatty acids have been detected in other insects.

There is evidence that certain insects are able to build up fat reserves from proteins. Abderhalden (2) raised beetles (*Anthrenus museorum*) on defatted silk and found that they developed normal fat reserves. Hoffmann (8), Frank (4), and Nishikata (14) fed larvae of the fly *Musca vomitoria* on defibrinated blood. Weinland (24) raised Calliphora on artificial protein medium. They all concluded that proteins were utilized in building up fat reserves. There is some evidence that insects may use carbohydrates, especially insects feeding on foods low in fat content. Timon-David (20) thought that certain wood-boring larvae which he studied synthesized fat from pentoses. Lacaze-Duthiers and Riche (11) analyzed insect galls and found them rich in starch but low in fat, while the larvae contained much fat. They thought that starch might have been utilized in fat formation.

The digestion of fat and the presence of lipases has been investigated by quite a number of workers, Sanford (18), Abbott (1), Swingle (19), Wigglesworth (25), Brown (3), etc. Lipase appears to be widely distributed in insects.

From literature so far published there appears no work on the definite factors which determine the kind of fat stored in the development of a given insect. This paper presents the results on the first experiments on the factors influencing the characteristics of the fat stored during the larval life of the corn earworm. Work of this kind has been done on dogs (Lebedev (12)) and on swine by Henriques and Hausen (6 7) and others.

The fat metabolism of insects furnishes a fertile field for investigation and may reveal factors determining the ability of insects to withstand hibernation temperatures and thereby influencing insect abundance.

EXPERIMENTAL METHODS

Young larvae were reared on various kinds of food in the laboratory. When in the pre-pupal stage they were killed, preserved, and stored at low temperature. Later during the winter months, the fat was extracted, dried, and certain physical and chemical characteristics determined according to the Official Methods of Associated Agricultural Chemists.

Rearing and Preservation of Material

Material was collected in the field and reared in the laboratory on four kinds of food, tomatoes, string beans, milk stage corn, and dough stage corn. Because of the cannibalistic habit of the larvae they could not be placed together. In case of larvae reared on tomato or beans, four-dram pill vials were used, and it might be said that they were very unsatisfactory: they held but little food, were difficult to fill and clean. There was considerable mortality among very young larvae; therefore second and third instar larvae were collected and reared on the desired food. In the cases where dough stage and milk stage corn were used as food, ears of the desired age were pulled and brought into the laboratory where they were placed in a specially constructed rack which sat in a tin tray. The larvae were allowed to finish their growth in the ears. The mature larvae on leaving the ears fell into the tin tray where they remained until collected.

The larvae were killed by splitting them open lengthwise with a small pair of scissors, and were immediately dropped into 95% alcohol at 70°C. at which temperature they were held for one hour by means of a water bath. The material was then cooled and placed in storage at 0°C. after the addition of a little sulfuric ether.

Extraction and Preparation of Sample.

The ether-alcohol solution in which the larvae were preserved was found to contain considerable quantities of fat. This solution was drained off the larvae, evaporated under partial vacuum to a small volume: fatty materials were then obtained by shaking out with ether in a separatory funnel. Three to seven shakings were found to be necessary, depending on the size of the sample.

The solid larval residue was extracted with ether, then dried 24 hours in the air at room temperature, ground in a mortar and re-extracted with ether. The ethereal solution from the first extraction, that is, of the undried larvae, was found to contain some water. This was removed in a separatory funnel and shaken with ether to insure getting all the fat. After extraction was complete all ethereal solutions derived from a given sample were added together, and evaporated under vacuum. The fatty residue was then placed under a vacuum of 40 to 50 mm. pressure for 15 to 18 hours with a slow stream of dry air passing over it. After this treatment the fat residue appeared to be dry. A sample treated as above was placed in an oven at 100°C. for a short time and was found to undergo no change in the refractive index.

RESULTS

The refractive index, specific gravity, saponification number, and content of free fatty acids were determined on the fat from larvae fed on dough stage and the larvae fed on milk stage corn. The fat secured from larvae fed on beans and tomatoes was not sufficient to make all these determinations. The results are given in Table XXVI. The refractive index was determined at 40°C. and the specific gravity at the temperature of boiling water. The Hamus method was used for the iodine value. Free fatty acid is figured as percent oleic acid.

Table XXVI. Showing certain characteristics of fat from larvae fed on various kinds of food, 1930-31.

Larval food	Refractive index	Specific gravity	Iodine value	Saponification number	Free fatty acid
Dough stage corn	1.4618	.8985	80.6	195.9	.68
Milk stage corn	1.4603	.8958	67.8	193.2	.64
Beans	1.4617		73.9	197.1	
Tomato	1.4615		70.5		

The most significant fact revealed from these experiments is the difference in iodine number with the various kinds of food, especially corn of different ages. The increase in iodine number of the insect fat may correspond to an increase in the iodine number of the ageing corn with its accumulation of fat. Ivanow (10) found that in some plants, flax, for example, the iodine number increased with the ripening of the seed whereas in certain other plants the iodine number remained constant or nearly so.

It is interesting, also, to note here the work of Philips and Barber (15) on hibernation. They found individuals fed on dough stage corn had a greater tendency to hibernate than those fed on milk stage corn, tomatoes or beans. The success of hibernation here is apparently strongly correlated with the high iodine number of the fat.

CONCLUSIONS

The character of fat accumulated by larvae of the corn earworm during their growth is apparently influenced by the kind of food which they consume.

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