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Biology and Control of the Southern Corn Rootworm

By
F. S. ARANT
Assistant Entomologist

AGRICULTURAL EXPERIMENT STATION
OF THE
ALABAMA POLYTECHNIC INSTITUTE

M. J. FUNCHESS, Director
AUBURN, ALABAMA

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INTRODUCTION

THE southern corn rootworm*, more generally known as the "budworm", is a serious pest in Alabama and throughout the South. It has long been known as an enemy to early corn on bottom lands, but with the increased use of winter legumes as soil building crops in Alabama, it has assumed a somewhat different role. Adults, known as the twelve-spotted cucumber beetles, congregate upon the legume crops during the winter and early spring months and deposit their eggs in the soil. The eggs hatch and the larvae often produce serious injury to corn which usually follows the legume. The adult is a pest of less importance upon melons, cucurbits, flowers, and a few other crops.

Studies of the biology and control of this insect were begun in the summer of 1926 and have been continued to the present. The main purpose of the project as originally planned was to determine the life history and a method of preventing larval injury to corn following the turning of winter legumes; but the scope was later broadened so as to include other phases of the biology and control of adults. The data contained in this report are on the work done from June 1926 to June 1929. The life-history work is practically complete, but certain other phases of the biology and the control are as yet not complete.

DISTRIBUTION

The southern corn rootworm is found in practically all parts of the United States east of the Rocky Mountains, in southern Canada, and in Mexico (17, 33, 37). It is most abundant in the southern part of the United States and causes the greatest amount of damage in the Gulf Coast States. The variety tenella occurs in Texas, Arizona, and southern California.

HISTORY AND AVAILABLE LITERATURE

The adult of the southern corn rootworm was first described

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†Also presented as a thesis to the faculty of the Alabama Polytechnic Institute in partial fulfillment of the requirements for the Master of Science degree.

*Diabrotica duodecempunctata, Fabricius; order Coleoptera, family Chrysomelidae. For the sake of brevity the term Diabrotica 12-punctata is used throughout this report.

in 1775 by Fabricius (18) as Chrysomela 12-punctata. According to Isely (31) the first reference to the adult in the literature of economic entomology was by Glover, who in 1854 mentioned it as feeding upon the petals of cotton plants; and the first record of larval injury to corn was probably by Yancey, from Virginia, in 1828. In more recent years, scores of investigators have made notes upon the biology, economic importance, and control of this insect. Literature is now available from most sections of the United States and from Canada (Bibliography, page 44). Some of the publications contain mere references to the southern corn rootworm as related to other studies, while others are fairly comprehensive in scope.

Among the publications worthy of special mention, are those by Chittenden (11, 12), Webster (65, 66, 67, 68), Thomas (60), Quaintance (41), and Luginbill (34), on phases of biology and control. Webster's publications are especially good. Creditable publications of still more recent date are those of Sweetman (58) and Isely (31). Sweetman in 1926 reported the results of detailed life-history studies made on a small number of individuals in Iowa, while Isely in 1929 published some data on the duration of developmental periods in relation to temperature, as well as data on certain other phases of biology and control on bottom lands in Arkansas.

While the aforementioned reports contain much valuable information, none of them are thoroughly comprehensive and complete. Most of them are on work done in the South, yet none of them give a complete life history for the South; none of them give data on larval injury to corn following winter legumes; and very few give actual data as to the best time to plant corn on bottom lands to prevent larval injury.

FOOD PLANTS

Plants Attacked by Adults

Adults of the southern corn rootworm are almost omnivorous in their feeding habits. They may be found upon most species of field and garden plants, but are especially attracted to winter legumes, cucurbits, tomatoes, ornamental plants, and fruit crops. They feed primarily upon the pollen, petals, and essential flower organs of the two latter groups, as well as of many other flowering plants. While the flowers and pollen of practically all plants serve as food, adults have also been observed at Auburn feeding upon the leaves or tender stems of the following plants**:

Alfalfa* (Medicago sativa), Asparagus* (Asparagus officinalis), Aster (Aster linariifolius), Bush bean (Phaseolus vulgaris nanus), Lima or butter bean (Phaseolus lunatus), Pole bean (Phaseolus vulgaris), Cabbage (Brassica oleracea capitata),

*Observed by Turner (61).

**Technical names of plants from Mohr (38) and Gray (28). A few also by courtesy of Professor J. F. Duggar.

Candy tuft (Umbellata sp.), Cantaloupe (Cucumis melo cantelupa), Chrysanthemum (Apiosporium sp.), Bur clover (Medicago arabica), Red clover (Trifolium pratense), Collard (Brassica oleracea acephala), Corn (Zea mays), Cotton (Gossypium herbaceum), Cucumber (Cucumis sativus), Dahlia (Dahlia variabilis), Dandelion (Taraxacum taraxacum), Fenugreek (Trigonella foenumgraecum), Lettuce (Lactuca sativa), Muskmelon (Cucumis melo reticulus), Mustard (Brassica nigra), Oats* (Avena sativa), Austrian pea (Pisum arvense), Canadian field pea (Pisum arvense), Cowpea (Vigna catjang), Grass pea (Lathyrus sativus), Tangier pea (Lathyrus tingitanus), Sweet pea (Lathyrus odoratus), Irish potato* (Solanum tuberosum), Sweet potato (Ipomoea batatas), Rye* (Secale cereale), Squash (Cucurbita melopepo), Tomato (Lycoperscium esculentum), Turnip (Brassica rapa esculenta), Common vetch (Vicia sativa), Hairy vetch (Vicia hirsuta), Monantha vetch (Vicia monantha), Purple vetch (Vicia atropurpura), Scotch vetch (Vicia sp.), Wooly pod vetch (Vicia dasycarpa), watermelon (Citrullus vulgaris), Wheat* (Triticum vulgare).

Of this entire list of food plants, candy tuft (Umbellata mixed) is perhaps the most attractive. On June 7 and 8, 1928, 184 beetles were collected from a row of candy tuft about four feet long; and large numbers could have been collected any succeeding day for more than a week. The plants, which were from four to twelve inches in height, were completely defoliated. Many of the tender stems were partially devoured and the plants were completely dead at the end of two weeks, at which time beetles were no longer present.

Besides the cultivated plants they commonly feed upon, adults were found by Sell (49) upon 280 other plants. Webster (68) has aptly said that a complete list of food plants would be most interesting for what it did **not** contain.

Plants Attacked By Larvae

Less work has been done toward determining the food plants of larvae, but they also apparently feed upon a great variety of species. They have been observed by the author feeding upon the roots or stems of corn (Zea mays), cucurbits (Cucurbita melopepo and Cucumis melo cantelupa), Austrian pea (Pisum arvense), and hairy vetch (Vicia hirsuta). Corn is the preferred food plant, but vetch and peas are also rather attractive, as indicated by the greed with which larvae feed upon them. Some of the other food plants recorded are as follows:

Rye (Secale cereale), and Southern chess (Bromus uniloides) (41); Barn yard grass (Echinochlea crus-galli), Oats (Avena sativa), and Wheat (Triticum vulgare) (68); Golden glow (Rudbeckia sp.), Jamestown weed (Datura stramonium), and Millet (Panicum miliaceum) (11); Johnson grass (Sorghum halepense) (46); and Peanut (Arachis hypogaea) (20).

NATURE AND EXTENT OF INJURY

Adult Injury

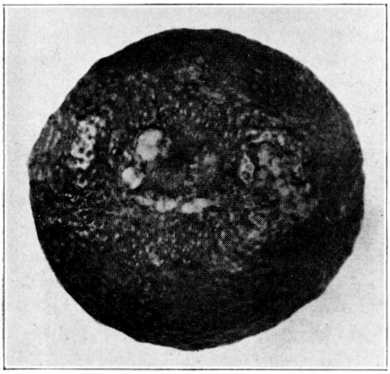

Fig. 1.—Citrus Fruit Injured by Adults of the Southern Corn Rootworm. Photograph by Courtesy of Dr. L. L. English, Spring Hill, Alabama.

The adult of this insect is much less destructive than the lava, but may cause serious injury to foliage. The beetles, when feeding, eat holes through the leaves or petals of the plant and completely devour the areas attacked. Nothing in the nature of a network remains. The attack may be confined to the pollen and flower parts or it may extend to the leaves and stems or even to the fruit (Fig. 1). The injury is usually of a more or less minor nature. In one instance previously mentioned, however, the plant attacked (candy tuft) was killed outright. This was an extreme case.

Larval Injury

The larvae are voracious feeders and cause severe or even fatal injury to young corn plants. They may feed upon the roots or bore into the base of the stem. In the former case, it is difficult to determine the exact extent of the injury. The plant becomes stunted and appears yellow in color but may later become more vigorous and produce grain. In the latter case, the larva drilling inside the stem of the plant causes the bud to wither and die (Fig. 2). The entire plant is often killed outright. According to Luginbill (34), if it is not killed, the suckers which arise are of little value.

Larvae attack other plants in much the same manner as corn, but the injury is apparently less severe. They attack the nodules and roots of vetch and winter peas and the roots and basal stems of cucurbits. Visible injury to these plants has not occured, however, at Auburn.

The rate of damage gradually increases with the increase in size of the larvae. The greatest amount of injury to young corn is consequently done by larvae from two to three weeks old. This does not mean that younger larvae are incapable of causing serious injury.

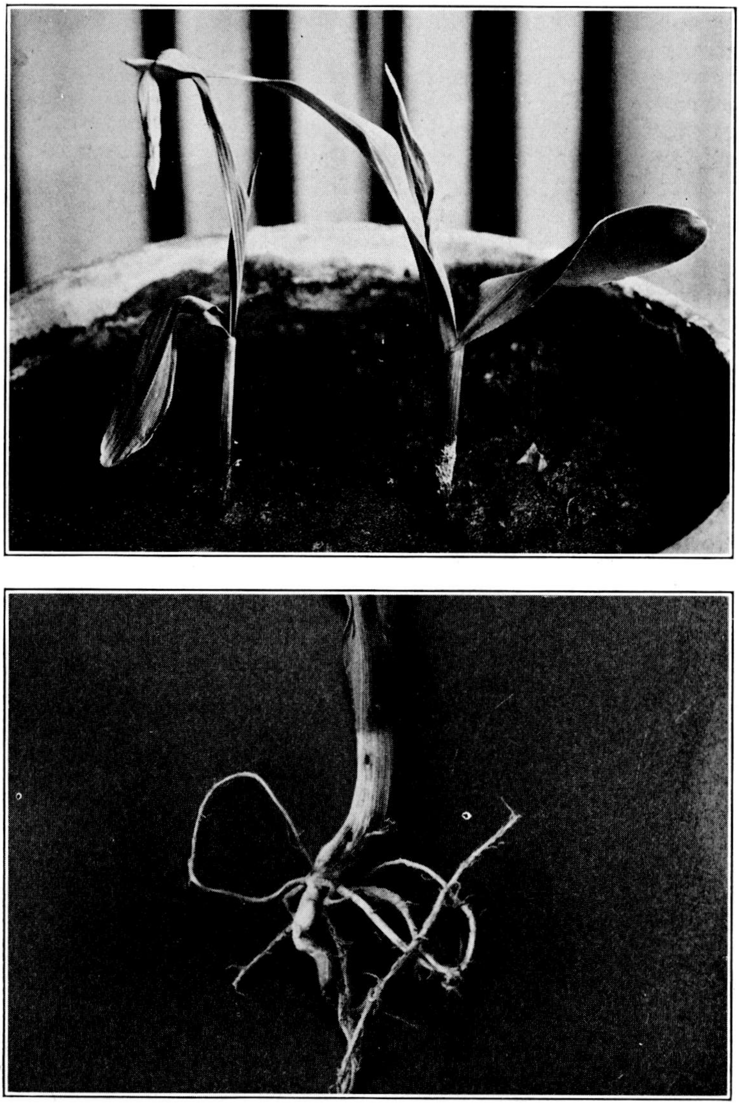

Fig. 2.—Corn Seedlings Injured by Southern Corn Rootworms. Note the Wilted Buds (Above) and the Holes Drilled in the Base of the Stem (Below). (Photographs by Hall in Ark. Agr. Expt. Sta. Bul. 232. Cut by courtesy of Arkansas Agricultural Experiment Station.)

PARASITES

Occurrence and Habits

The southern corn rootworm is troubled with but few parasitic enemies. The only one encountered during these studies was the larva of a tachinid fly, (Celatoria diabroticae) which occurs in the adult stage of D. 12-punctata. It was encountered much more frequently infesting the beetles in the late winter and early spring months than later in the year.

The parasitic larva lives within the abdomen of the beetle and feeds upon the vital organs, finally causing the death of the beetle. After death occurs, the parasite continues to feed for two to five hours. It begins in the abdomen of the beetle, and feeding voraciously by means of two slender jaws, devours all the internal organs as far forward as the head. Finally, the abdominal exoskeleton is torn from the thorax and the parasite crawls out to pupate. Pupation usually occurs within one or two hours in the crevices of the soil.

The parasite remains in the pupal stage approximately three weeks during February or early March, but remains in this stage little more than one week during the hot summer months. At the end of the pupal period, the two-winged fly emerges.

Little is known about the habits of the adults. Reinhard (5) reports collecting a large number of specimens from flowers and grasses in Texas throughout the spring and summer of 1919. The author has observed them feeding upon sugar syrup and fermented bananas. He has also observed them hovering about Austrian peas (Pisum arvense).

Effect Upon The Host

Parasitized beetles begin to appear abnormally yellow in color a week or more before death occurs. They also become less active and cease to feed. At times the hind legs are rubbed against the pleura of the abdomen and metathorax, the antennae are twitched nervously, and the ovipositor may be protruded and retracted. As death draws nearer, the beetle rarely ever moves except when disturbed and even then stumbles along very clumsily. Movements of the parasite are plainly visible through the abdominal wall of the beetle for two or three days before death occurs.

Description of Stages

The adult parasite is a two-winged fly about five mm. in length. The eyes are bare and reddish in color. The fifth abdominal segment of the female is equipped on the under side with a strong sharp piercing organ, the free end of which extends forward to a longitudinally compressed process, armed at the apex with numerous small tubercles, on the ventral side of the second abdominal segment. In the male this process is wanting and the venter is normal.

This insect was originally described by Coquillett (3) as Celatoria crawii. Crawii was later placed in synonomy with diabroticae. The original description follows:

> Male. Frontal vitta blackish-brown, sides of front white, tinged with yellow; face white; palpi reddish-yellow; antennae black. Thorax grayish-black, destitute of stripes, the bristles not disposed in rows. Scutellum grayish-black. Abdomen black, mottled with gray, destitute of reddish spots; fifth segment scarcely one-fourth as long as the fourth; a posterior dorsal pair of bristles on the first and second segments, and a posterior transverse row of bristles on the third, fourth, and fifth segments, besides several along the sides of the abdomen; venter concolorous with the dorsum. Legs black, claws and pullvilli much shorter than last tarsal joint. Wings hyaline. Alulae white. Halteres yellow.
>
> Female. Same as male except that there is a median pair of bristles on the second, third, and fourth segments. Length 4½ to 5½ mm.

There seems to have arisen some confusion as to the characters which distinguish Celatoria diabroticae from related forms. Chittenden (2) states that Chaetophleps setosa, also a parasite of Diabroticas, closely resembles C. diabroticae; and the photographs he gives appear almost identical with those of C. diabroticae. Reinhard (5) states that the differences distinguishing Tachinophyto floridensis from C. diabroticae are obscure, while Coquillett's (3) generic description of Celatoria males contains certain characters apparently applicable to females of the parasite encountered at Auburn, but not to males. The author is unable to clarify the existing confusion.

The parasites occurring in the adults of D. 12-punctata at Auburn were identified at the U. S. National Museum as males and females of Celatoria diabroticae.

Larva. Possesses typical tachinid characters. Light brown, thickly covered with spines of a darker shade. Length about 7 mm.; cylindrical, broad at the posterior end, tapering anteriorly. A pair of slender, retractile hook-like jaws at the anterior end.

Paparium. "Dark brown, cylindrical, the ends rounded; quite thickly covered with black spines of varying length, some of the longer ones converging and adhering to each other, forming clusters of from 8 to 14 spines; length 4½ mm." (3).

Economic Importance

Previous writers* have referred to C. diabroticae as being of little importance in reducing the numbers of D. 12-punctata, due to the infrequent occurrence of the parasite. Their conclusions are no doubt based largely upon observations made during the late spring or summer months, as few parasitized beetles are to be found at that time. Early in the year, however, parasitized beetles may be found in much larger numbers.

Fourteen per cent of the 43 beetles collected from the fields

*Isely (31), Webster (68), Luginbill (34), and others.

at Auburn from January 24 to February 14, 1927, were parasitized (Table 1, page 12). Only one parasitized beetle was collected after the latter date, and the per cent of parasitism declined steadily to 4.72, November 3. In 1928 twelve per cent of the 76 beetles taken from the fields between January 30 and February 14, were parasitized. Only two parasitized beetles were collected after the latter date and the percent of parasitism declined to 6.06, October 6. In 1929, beetles were collected earlier than in either of the previous years. Of the 64 beetles collected from January 8 to 23, nineteen per cent were parasitized. No more beetles were collected until March 8. Twenty-six were collected on that date, none of which were parasitized.

These data show that C. diabroticae is rather efficient in reducing the numbers of D. 12-punctata during January and early February, but is much less efficient during the spring and summer months. Since serious injury to corn is produced almost exclusively by larvae of the overwintered adults, this relatively high percentage of parasitism among these adults in January and February necessarily reduces the number of larvae produced to infest the corn. The extent of this reduction is best comprehended when considered in connection with the fact that slightly more than 70 per cent of the overwintered adults are females (Table 23, page 31).

Method of Infestation

The exact method of infestation is apparently unknown. Luginbill (34) states that the fly "places a maggot or larva in the abdomen of the beetle" by means of the sharp piercing organ located ventrally on the second and fifth abdominal segments of the female. Just how this "placing" occurs is not explained.

The author has made several unsuccessful attempts to determine the exact method of infestation.

DESCRIPTION OF STAGES

The Adult

The adult of the southern corn rootworm was originally described by Fabricius (18) in 1775 as Chrysomela 12-punctata. Horn (30) in 1893 published a good description which was reprinted by Isley (31) in 1929. Blatchley (7) has also written a brief but accurate description.

The original description follows:

> C. oblonga, thorace flavescente, elytris viridibus: punctis sex nigris.
>
> Habitat. . . .
>
> Statura et magnitudo C. alni, Capnut nigrum. Antennae nigrae, articulo secundo et tertio verescentibus. Thorax flavescens puncto utrinque impresso. Elytra viridia, punctis sex nigris distinctis per paria dispositis. Pectus nigrum, abdomen et pedes flavescentes.
>
> —Fabricius (18).

The following is the author's translation of this description:

> Oblong Chrysomela, thorax yellow, elytra green with six black spots.
>
> Habitat.
>
> Size of C. alni. Head black. Antennae black, second and third segments light green. Thorax yellow, marked on each side with an impression. Elytra green, six distinct black spots evenly arranged. Breast black, abdomen and feet yellow.

This insect may be further briefly described as follows:

Oblong-oval, narrower in front; variable shades of yellowish green, each elytron with six conspicuous black spots as shown in Fig. 3; head and prosternum black; antennae dark, extending more than half the length of the body, three basal joints pale; thorax wider than long, disc convex with a fovea on each side of middle; elytra wider behind, sparsely and finely punctate; legs piceous, basal half of femora pale. Females containing eggs, broad and plump; abdomen sometimes greatly extended with 2-3 posterior segments exposed from above. Length 6-7.5 mm.

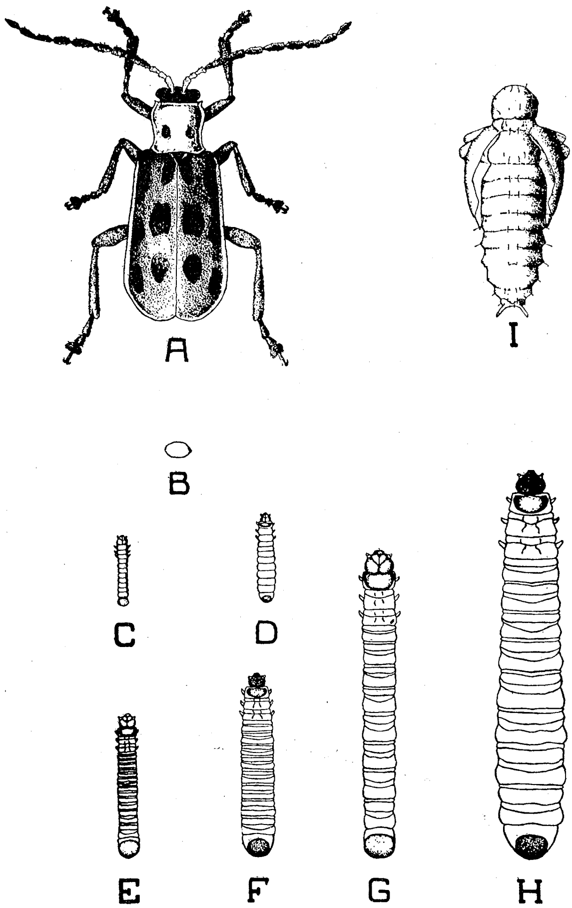

Fig. 3.—The Life-History Stages of the Southern Corn Rootworm (enlarged about 4½ times). A, Adult; B, Egg; C-H Larvae: C, soon after hatching; D, near the end of the first instar—just preceding the first moult; E, after the first moult; F, near the end of the second instar—just preceding the second moult; G, after the second moult; H, near the end of the third instar—just preceding the prepupal period and the third moult; I, Pupa.

The Egg

The egg is light yellow in color at the time of deposition and becomes a deeper yellow with age. The size and shape are somewhat variable, some eggs being considerably shorter and thicker than others. The general shape, however, is oval and the average size is about .7 mm. long and .5 mm. wide (Fig. 3). Eggs are often mashed slightly during oviposition and consequently appear flattened. The surface of the egg is covered with minute hexagonal pits.

Table 1.—The Number of Beetles Collected and the Per Cent Parasitized Throughout the Year. 1927-1929.

1927			1928			1929		
No. of Beetles	Date Collected	Per Cent Parasitized	No. of Beetles	Date Collected	Per Cent Parasitized	No. of Beetles	Date Collected	Per Cent Parasitized
3	Jan. 24	0.00	24	Jan. 30	12.50	7	Jan. 8	28.57
1	Feb. 5	0.00	13	Feb. 2	7.69	57	Jan. 23	17.54
16	Feb. 10	12.50	2	Feb. 8	50.00	26	Mar. 8	00.00
23	Feb. 14	17.39	12	Feb. 9	0.00			
25	Feb. 16	4.00	25	Feb. 14	16.00	15	June 23*	13.33
2	June 8	0.00	17	Mar. 5	00.00			
35	Aug. 1	0.00	3	June 6	00.00			
15	Sept. 16	0.00	51	June 7	3.92			
9	Sept. 17	0.00	19	June 8	00.00			
7	Sept. 20	0.00	16	Oct. 6	00.00			
6	Oct. 27	0.00						
6	Nov. 3	0.00						
Total 148		Av. 4.72	Total 182		Av. 6.06			

*1926 instead of 1929.

The Larva

The larva is yellowish white in color and has a rather conspicuous greyish brown head; the dorsal surface of the ninth abdominal segment is partially covered by a rounded shield, brown in color; and the body is subcylindrical in shape, is somewhat curved, and tapers slightly anteriorly (Fig. 4). Shortly

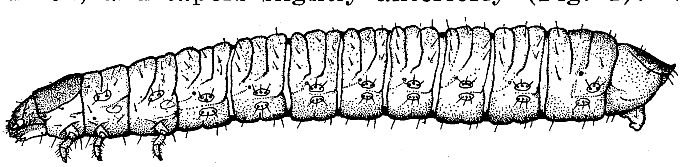

Fig. 4.—The Mature Larva.*

after the larva emerges from the egg and immediately following each moult, the head and anal shield are light in color and appear broad in proportion to the size of the body which is at that time extremely slender. Just previous to each moult, the head and anal shield are dark and considerably narrower than the body which is rather plump (Fig. 3). At the time of hatching, the larva is about 1.85 mm. long and has a head

*Drawing by Hall in Ark. Agr. Expt. Sta. Bul. 232. Cut by courtesy of the Arkansas Agricultural Experiment Station.

capsule approximately .27 mm. wide. The mature larva is about 12 mm. long and 1.5 mm. wide, and has a head capsule approximately .6 mm. wide. Locomotion is effected by means of the three pairs of short, stout thoracic legs and the fleshy anal proleg which is a development of the ventrally located tenth abdominal segment.

A detailed description of the mature larva has been published by Boeving (10). This description is accompanied by drawings. showing the principal structures described and the location of the numerous spines which occur on the body.

The Pupa

White, turning light yellowish with age. Head bent downward. Wings longer than elytra; length of both varying with the age of the pupa. Abdomen 9-segmented, tapering posteriorly; seventh segment longer than eighth and ninth combined, the

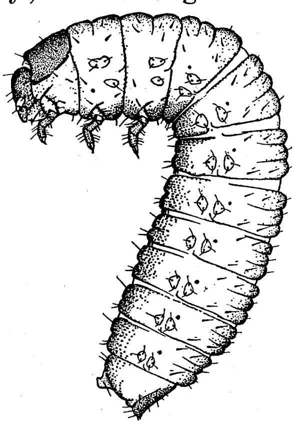

Fig. 5.—The Prepupa.*

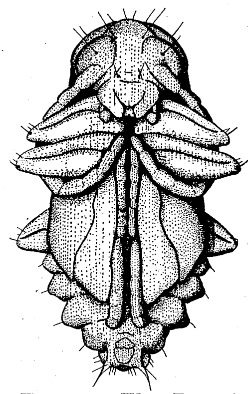

Fig. 6.—The Pupa*.

ninth bearing a pair of long, stout spines; segments one to six each bearing a pair of small dorsal spines, seven and eight two pairs. Prothorax with five pairs of dorsal spines; mesothorax and metathorax each with two pairs. Tips of first and second pairs of femora exposed from above. Length (preserved specimen) about 6.25 mm.; greatest width about 3.5 mm. (Fig 3 and 6).

LIFE HISTORY AND DEVELOPMENT

Experimental Methods

The beetles used in the life-history studies were confined in glass vials 114 mm. high and 40 mm. in diameter. A circular piece of moist blotting paper was placed in the bottom of each vial and a cotton plug, wrapped in cheese cloth, was placed in the mouth. Bean leaves were used primarily for food, although cucurbit and tomato leaves were also occasionally used. The stems of the leaves were wrapped with moist absorbent cotton to keep the food fresh. Observations were made

*Drawing by Hall in Ark. Agr. Expt. Sta. Bul. 232. Cut by courtesy of the Arkansas Agricultural Experiment Station.

daily, eggs were removed and counted if present, and fresh food was added when necessary.

Eggs, larvae, and pupae were reared in glass vials 60 mm. high and 30 mm. in diameter. The moisture necessary for development was maintained by moist absorbent cotton placed in the bottom of the containers. Upon hatching, the young larva was removed from the incubation vial and placed upon sprouted corn. The grain of corn rested upon the bottom of the vial and the absorbent cotton was placed upon it in such a way that the sprout grew up between the side of the glass container and the cotton. Roots were produced beneath the cotton; and the larva feeding upon them could be readily observed. A grain of corn bearing a sprout about one inch long was found to be best for a very young larva, while a larger sprout was more satisfactory for an older larva. When it became necessary to change the food, the larva was transferred by means of a small soft camel's hair brush, and the cotton was pressed down upon the sprouted corn before the larva was placed upon it. Soil was added to the vial when the prepupal stage was reached. This method of rearing proved very satisfactory as it permitted accurate observations, required little space, induced a low mortality rate, and demanded few changes of food and consequently little transferring of larvae.

The life-history studies were carried on in the research laboratory. The containers of the various stages were kept on the broad window sills just outside the laboratory on the east side of the building. A screen of cello-glass served as a protection against rain and sheets of pasteboard were used on hot days to protect the adults from the direct rays of the sun. A hygrothermograph was kept in one of the windows, while the local climatological station was located about 400 yards east of the laboratory. The temperature records at the two stations correlated closely, and the data from the climatological station were used in this report.

While the experimental methods used in these studies were very satisfactory, a great many other methods have been employed by previous investigators with various results. Sweetman (58), who was the first investigator to rear all stages, used a method quite similar to the one just described, the major differences being that cucurbit stems instead of sprouted corn were used for larval food and moist soil instead of moist cotton was used in the rearing vials. Isely (31), who was the next and only other investigator to rear all stages, confined the adults in glass battery jars and reared the developmental stages in salve boxes about half filled with soil. The larvae were fed various foods with more or less unsatisfactory results until freshly sprouted corn was adopted.

Another simple method of rearing root-feeding larvae has been worked out by Searls (48) and deserves mention. He used Petri dishes containing plaster of Paris covered with pieces of blotting paper. The young seedlings used as food were placed in the Petri dishes between the plaster of Paris and the blotting paper which was saturated with a nutrient solution. This is apparently an excellent method where sufficient space is available to permit its use.

Seasonal History

Hibernation. The southern corn rootworm passes the winter in the adult stage (Fig. 9) but in Alabama no period of complete dormancy occurs. On cold days the beetles become inactive, but when the temperature rises again well above the freezing point, they become active once more and start feeding. Few or no eggs, however, are deposited during the late fall and early winter months.

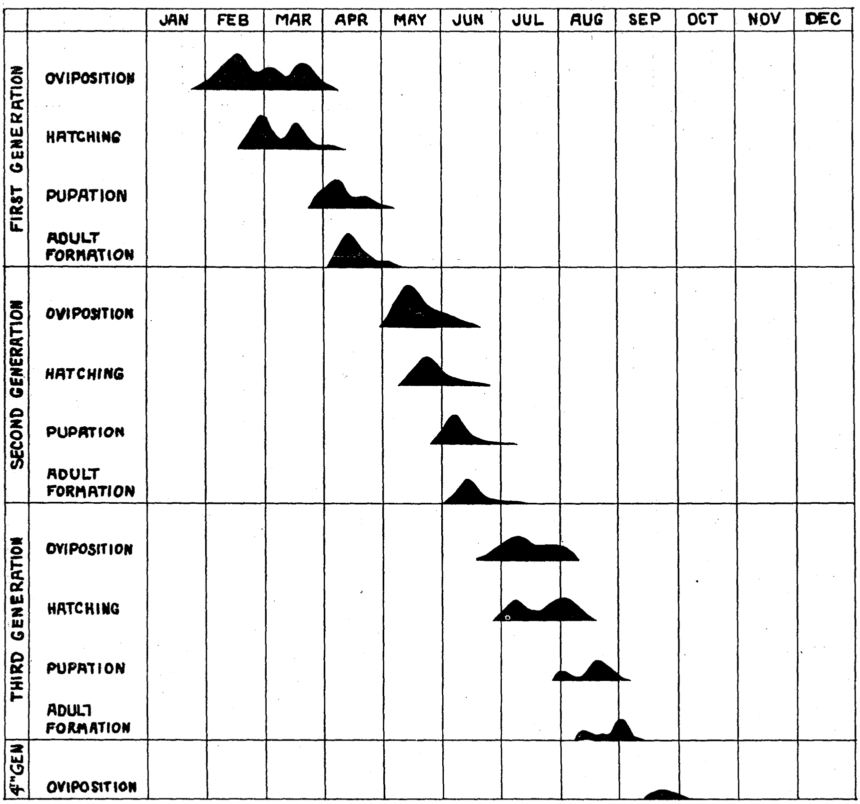

Fig. 7.—Graphic Summary of the Life History, 1927.

In 1927 more than fifty adults were under observation during the late fall and early winter. Oviposition ceased the first of October and had not been resumed January 1, 1928, when all the adults were killed by the temperature dropping to eight degrees F.

In the fall of 1928 a smaller number of individuals were under observation, five of which lived through the winter. Three of these five began oviposition between January 18 and 25, 1929.

The depositions January 18 were the first since October 4 of the previous year.

Field trips on cold days early in January 1929 revealed inactive beetles in straw, leaves, and rubbish. On warm days they were observed feeding on winter legumes. They were also observed inactive at the base of legume plants on cold days.

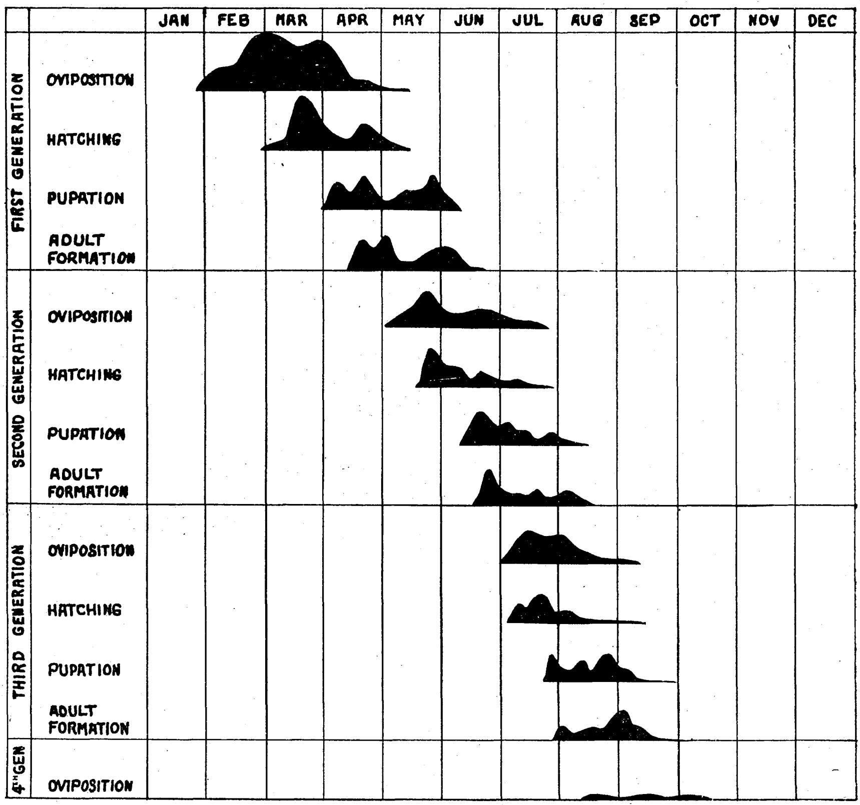

Fig. 8.—Graphic Summary of the Life History, 1928.

Number and Distribution of Generations. Sweetman (58) reported one generation a year in Iowa, while Isely (31) reported the number of generations in Arkansas as indeterminate. In both 1927 and 1928 there occurred three complete generations and a small part of a fourth throughout the year at Auburn (Figs. 7 and 8). It therefore seems logical to conclude that this is the normal number for that section of Alabama.

The distribution of generations necessarily varies from year to year, but Fig. 9, giving the seasonal distribution of adults and Fig. 10, giving the seasonal distribution of egg deposition, will convey an idea as to the seasonal distribution of generations. The third generation adults overwinter and become known as the overwintered adults the following spring. It is possible that a few beetles other than those of the third generation also overwinter, but their numbers are apparently small, if they exist at all.

Copulation

Females copulate only once, while males copulate at several different times if given an opportunity. Copulation in the laboratory at Auburn occurred when the females were from 5 to 18 days old, the average number of days in the prenuptial period being approximately nine (Table 2). This was an average of six days before the first and second generation females began oviposition. Most of the third generation females lived overwinter before depositing eggs. Mating individuals were connected for varying periods of time, ranging from half an hour to more than five hours, the average period being 3.22 hours. In instances where the same male copulated with more than one female, the mating period was of approximately the same length in each instance.

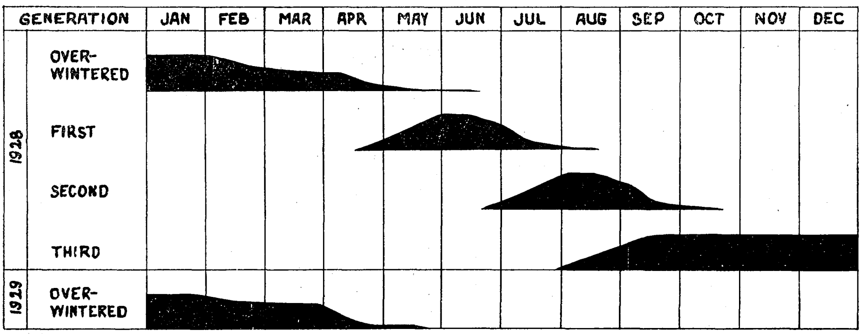

Fig. 9.—The Seasonal Distribution of Adults by Generations.

Sweetman (57) reports observing the unusual phenomenon of D. vittata males copulating with D. 12-punctata females. In one instance several offspring of a female so mated were reared, but no unusual forms resulted.

Table 2.—The Prenuptial Period of Females by Generations, 1928

Generation	Duration of Period (Days)			Number of Records
	Maximum	Minimum	Average	
First	15	6	9.2	11
Second	12	5	7.9	17
Third	18	12	14.3	3

Egg Deposition

Egg deposition is almost continuous from the latter part of January to near the middle of October (Fig. 10). The mass of first generation eggs is deposited in March, but considerable quantities may be deposited during both February and April.

In 1927 the deposition of first generation eggs in the laboratory at Auburn ceased early in April; in 1928 it continued into May; while in 1929 it ceased about the middle of April. The deposition of second generation eggs begins near the close of the first oviposition period, continues into mid-summer, and overlaps with the third period. The fourth generation eggs deposited are few in number and of little consequence.

Method of Oviposition. Eggs are normally deposited in crevices of the soil. The female protrudes her ovipositor, feels around over the surface of the soil with it until a crevice or soft place is located, forces the ovipositor into the soil at such a point, and deposits eggs there. After laying a few eggs at a given point, the female moves a short distance away and, after locating a suitable place by the method just described, deposits more eggs. In this more or less haphazard manner, an area of soil may be gone over more than once by the same female. The eggs may be deposited in groups or singly.

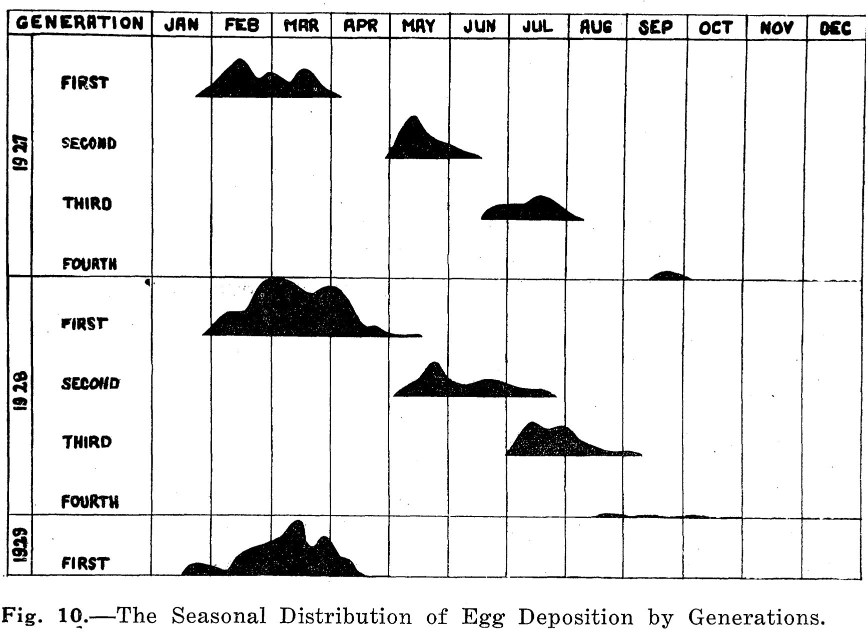

Fig. 10.—The Seasonal Distribution of Egg Deposition by Generations.

Many investigators* have stated that the female deposits eggs at the base of the corn upon which the young larvae will feed. The author believes this opinion to be unsupported by facts, since he has observed a female depositing eggs in soil containing young corn. The eggs were deposited at random and the area near the corn apparently received fewer eggs than areas farther away. He has also also observed serious injury to young corn

*Turner (61), Webster, R. L. (69), Luginbill (34), Chittenden (11), and others.

produced by larvae considerably older than the corn. In fact the most serious injury observed falls under this category.

The Pre-oviposition Period. Immediately after the female beetle emerges from the pupal cell, there follows a short period during which no eggs are deposited. Mating and almost continuous feeding occur during this period. It varies greatly in length among individuals of the different generations and varies to a lesser degree among the individuals of the same generation (Table 3). The pre-oviposition period of first and second generation adults is of approximately fifteen days duration, while the pre-oviposition period of third gerenation adults may be of several months duration.

Table 3.—The Pre-oviposition Period, by Generations, 1928

Generation	Duration of Period (Days)			Number of Records
	Maximum	Minimum	Average	
First	23	12	16.8	10
Second	19	8	13.7	15
Third*	20	20	20.0	1

*Most third-generation females overwinter before depositing eggs.

The Oviposition Period. Quaintance (41) states that the oviposition period is of only two or three days duration, while Webster (68) allows a few more days. In these studies it was found that the period might be as long as 90 days (Table 4). The average duration for overwintered adults was 43 days; for first generation adults, 18 days; and for second generation adults, 10 days.

Table 4.—The Oviposition Period, by Generations, 1928

Generation	Duration of Period (Days)			Number of Females
	Maximum	Minimum	Average	
Overwintered	90	1	43.6	38
First	31	1	18.3	13
Second	30	1	10.0*	20

*Probably too low due to a high mortality of adults.

The Number of Depositions.† The number of egg depositions varies directly with the duration of the oviposition period. The largest numbers are consequently made by overwintered adults and the smallest by second generation adults. In 1928 the average number varied from three depositions of third generation eggs to eight depositions of first generation eggs (Table 5).

†The term deposition as used here refers to the eggs deposited in one day.

Table 5.—The Number of Egg Depositions, by Generations, 1928

Generation	Number Depositions Per Female			Number of Females
	Maximum	Minimum	Average	
First	19	1	8.4	38
Second	13	1	6.5	13
Third	8	1	3.3	20

The Number of Eggs Per Deposition. The average number of eggs per deposition was fairly constant throughout the three generations in 1928 (Table 6). Among the females of a given generation, however, the number of eggs was quite variable, ranging from 1 to 147. The largest number previously reported was by Sweetman (58), who reported 122 eggs deposited by a single beetle in 24 hours.

Table 6.—The Number of Eggs Per Deposition, by Generations, 1928

Generation	Number of Eggs Per Deposition			Number of Depositions
	Maximum	Minimum	Average	
First	139	1	46.7	322
Second	147	1	46.8	85
Third	119	1	42.0	67

Total Number of Eggs Deposited. The total number of eggs deposited by a single individual has been a subject of much speculation and considerable investigation during the past two or three decades. Turner (61) estimated the average number to be about 75, but stated that in unusual cases as many as 200 may be produced; Sherman (51) also believed 200 to be an unusual number; while Luginbill placed the maximum number at 500. Maximum oviposition records obtained by other investigators were as follows: Chittenden (11), 202; Marsh (36), 515; and Sweetman (58), 895.

The maximum number deposited by a single beetle during these studies was 1198 (Table 7). These were first generation eggs deposited by an overwintered adult. The minimum number of four was deposited by a second generation female. Between these two extremes, the mass of production occurred.

Table 7.—The Deposition of Eggs, by Generations, 1928

Generation	Number of Eggs Per Female			Number of Females
	Maximum	Minimum	Average	
First	1198	40	396.1	38
Second	598	23	305.0	13
Third	584	4	158.5	20

Development

Relation to Temperature. Isely (31) found a high correlation between temperature and the rate of development at constant temperatures. The correlation was not always so pronounced at outdoor temperatures. He attributes certain inconsistencies largely to the kind of food used in the latter case.

The rate of development at controlled temperatures was not determined at Auburn, but the relation of outdoor temperatures to the rate of development was noted. In studying the rate of development at outdoor temperatures, not only the mean temperature for the day was considered, but also the maximum and minimum. Tables 8 and 9, therefore, contain maximum, minimum, and average mean temperatures for the periods involved. These temperatures were derived as follows: The maximum mean temperature for each individual stage involved was secured and the average for all the individuals was used as the maximum mean for the group; the minimum mean for each individual was secured and the average used as minimum for the group; and the average of the maximum and minimum means thus secured was used as the average mean.

Table 8.—The Incubation Period as Related to the Mean Temperature, 1928

Oviposition Date	Number of Eggs	Average Number Days Incubation	Mean Temperature (Degrees F.)		
			Maximum	Minimum	Average
Feb. 3	48	29.6	60.6	38.6	49.6
Mar 2	76	21.2	64.4	45.0	54.7
Apr. 2	51	19.9	71.3	49.7	60.5
Apr. 24	35	14.0	77.6	52.1	64.9
May 14	50	11.2	79.6	61.0	70.3
June 2	41	9.1	83.3	64.9	74.1
July 4	54	7.3	90.7	70.1	80.4
Aug. 5	11	8.0	92.3	71.6	81.9
Total	366				

The duration of the incubation period steadily decreased as the temperature increased until a maximum mean of 92 degrees F. was reached (Table 8). At this point, the maximum temperature apparently had passed the optimum for rate of development. The average mean temperature for the period, however, was approximately four degrees lower than the constant temperature found by Isely to be most favorable to rapid development. This fact is a further indication that the upper temperature limit, at which physiological development ceases, had been approached.

The duration of the total developmental period (egg to adult) showed a similar correlation to the temperature. The number of days in the period decreased steadily until the maximum mean temperature rose to 90 degrees F., and again apparently approached the upper limit beyond which development ceases (Table 9).

Table 9.—The Total Developmental Period as Related to the Mean Temperature, 1928

Oviposition Date	Number of Records	Average Number Days Development	Mean Temperature (Degrees F.)		
			Maximum	Minimum	Average
Feb. 3	10	80.9	65.5	45.2	55.3
Mar. 2	4	64.0	70.7	48.8	59.8
Apr. 2	4	57.5	74.7	53.4	64.0
Apr. 24	7	46.1	80.3	58.5	69.4
May 14	18	39.5	84.4	64.3	74.3
June 2	10	35.5	87.0	65.5	76.3
July 4	11	33.0	90.7	70.5	80.6
Aug. 5	5	33.0	88.0	70.7	79.4
Total	69				

In the discussion of temperature as related to development, attention should be called to the general complexity of the problem. It is obvious from the preceding discussions and tables that the total temperature represented by one average mean is not necessarily equivalent to the total temperature represented by another average mean of the same numerical value, but that the upper and lower limits must be considered. It is also apparent that development at controlled constant temperatures is not comparable to development at outdoor temperatures. Several well known factors enter into making development at outdoor and controlled temperatures incomparable, but one which is likely to be overlooked was discovered by Peairs (39). Peairs found that development at controlled constant temperatures was at a slower rate than development at controlled varied temperatures of the same value. He went further and presented data which show that temperatures undergoing a daily variation similar to the normal variations under outdoor conditions, accelerates the rate of development as compared to constant temperatures of the same apparent value. Data presented by Isely (31), while not mentioned in this connection by him, support Peairs' findings regarding the accelerated rate of development at outdoor temperatures.

Due to the multiplicity and complexity of the factors involved, it is not sufficient to determine the duration of developmental periods only in so far as they are related to temperature. This report, therefore, presents the developmental periods in relation to the time of the year and to the generation in which they occur as well as to the outdoor temperature. The two former relationships are discussed in the following pages.

The Incubation Period. The incubation period is the most variable stage of the life history. This is due largely to the fact that it occurs over the widest range of temperature, beginning with the low temperatures of late winter or early spring and continuing through the hot summer months.

In 1927 the duration of the incubation period varied from 25 days early in the year to as low as 6 days in mid-summer, while in 1928 it varied from a maximum of 47 days (55 in 1929) during the first part of the year to a minimum of 3 days during the midsummer months (Table 10). The range in duration of the average incubation periods was somewhat less in each instance, but the greatest average durations occurred early in the year and the lesser ones later.

While this wide range of variation was due largely to variations in temperatures during the different periods, other factors also entered into the situation. Eggs from certain females were observed to hatch in a shorter period than eggs from certain other females, even though the eggs of both were deposited the same day and incubated under apparently identical conditions.

Table 10.—The Incubation Period as Related to the Date of Oviposition, 1927 and 1928

Oviposition Date	Duration of Period (Days)						Number of Eggs	
	Maximum		Minimum		Average			
	1927	1928	1927	1928	1927	1928	1927	1928
Jan. 16-31		55*		45*		49.7*		9*
Feb. 1-15	25	47	11	26	19.4	35.9	38	413
Feb. 16-29	24	36	16	18	21.6	24.6	114	531
Mar. 1-15		38		16		21.2		968
Mar. 16-31	9	35	8	10	8.4	19.5	47	573
Apr. 1-15		35		11		21.2		197
Apr. 16-30		18		10		14.6		146
May 1-15	10	23	7	10	8.3	12.3	21	72
May 16-31		38		4		10.2		576
June 1-15		20		4		8.3		255
June 16-30	6	17	6	3	6	7.9	29	199
July 1-15		26		4		7.9		180
July 16-31	7	13	7	5	7	7.1	2	317
Aug. 1-15	7†	13	6†	7	6.8†	8.1	29†	30
Total							280	4766

*1929 instead of 1928.

†1926 instead of 1927.

Considerable variation also occurred among different eggs deposited at the same time by any given individual. When large numbers of periods are averaged, however, the individual factor is not of great consequence.

The incubation periods by generations are given in Table 11. The average period for each generation in 1928 was slightly longer than the average period for the corresponding generation in 1927.

Table 11.—The Incubation Period, by Generations, 1927 and 1928

Generation	Duration of Period (Days)						Number of Eggs	
	Maximum		Minimum		Average			
First	25	55	8	10	18.1	23.9	199	3037
Second	10	38	7	3	8.3	9.4	21	1136
Third	7	13	6	7	6.4	7.4	60	493

A few fourth generation eggs were deposited in both 1927 and 1928, but in each instance these eggs failed to hatch. The reason for their failure to hatch is not known, since some of the eggs were from females known to have copulated previous to the deposition. Each of these females, however, copulated with the same male and it is possible that he was sterile. Since Isely obtained incubation records in Arkansas as late in the year as most of these eggs were deposited, it appears likely that the eggs in question were simply infertile.

The Larval Period. At the end of the incubation period, the young larva gnaws through the covering of the egg and emerges. It then begins an independent existence. The first part of its existence is a period of great activity in which feeding, growth, and moulting occur; while the latter part is a period of inactivity and rest, known as the prepupal period.

ACTIVE PERIOD. The active larval period consists of the first two instars and a part of the third. Feeding is practically continuous throughout the period, which varies considerably in length of duration. The active periods for 1927 and 1928 as related to the time of year in which the stages occurred are shown in Table 12. The average duration varied from 16 to 27 days in 1927 and from 13 to 29 in 1928.

Table 12.—The Active Larval Period as Related to the Date of Oviposition, 1927 and 1928

Oviposition Date	Duration of Period (Days)						Number of Larvae	
	Maximum		Minimum		Average			
	1927	1928	1927	1928	1927	1928	1927	1928
Feb. 1-15	35	40	20	22	27.5	29.0	11	31
Feb. 16-29	28	33	20	27	24.3	30.3	6	3
Mar. 1-15		29		24		26.1		6
Mar. 16-31		39		19		26.9		15
Apr. 1-15		24		17		20.1		18
Apr. 16-30		27		16		19.6		19
May 1-15	25	25	13	14	16.8	16.7	5	24
May 16-31		23		14		16.7		13
June 1-15		25		12		16.2		31
June 16-30	18	26	15	14	16.0	18.7	4	11
July 1-15		27		11		14.9		25
July 16-31		17		11		13.7		24
Aug. 1-15	19*	17	15*	12	17.2*	14.0	15*	6
Total							41	226

*1926 instead of 1927.

The duration of the active larval periods by generations is given in Table 13. The longer periods in both 1927 and 1928 occurred in the first generation, and the shorter ones in the later generations. The maximum period for the two years was 40 days and the minimum was 11.

Table 13.—The Active Larval Period, by Generations, 1927 and 1928

Generation	Duration of Period (Days)						Number of Larvae	
	Maximum		Minimum		Average			
	1927	1928	1927	1928	1927	1928	1927	1928
First	35	40	20	16	26.4	24.8	17	92
Second	25	27	13	12	16.8	16.7	5	90
Third	18	17	15	11	17.0	13.7	19	44

Number and Duration of Instars. The first two instars and a part of the third occur during the active larval period. The latter part of the third is passed in the prepupal or resting stage. Table 14 summarizes the duration of stadia periods of active larvae as related to the date of oviposition, while Table 15 gives the same data by generations. The third instar was usually the longest, the second the shortest, and the first intermediate regardless of the time of the year at which the stages occurred or the generation to which they belonged. This was true, of course, only when applied to instars occurring in logical sequence at any time of year. The number of stadia days for all the instars was larger early in the year and smaller later in the year, varying from an average of 11 for the first instar, 10 for the second, and 14 for the third early in the year to as low as 4 for the first, 3 for the second, and 5 for the third during the summer.

Width of the Head Capsule. The width of the head capsules was determined by measuring living or recently killed larvae with a standardized micrometer eyepiece. It was sometimes necessary to etherize a living larva before a measurement could be made.

The average width of the head capsule was for the first instar .274 mm., for the second instar .402 mm., and for the third instar .604 mm. (Table 16). These sizes are considerably larger than those reported by Sweetman (58), due at least in part to the fact that Sweetman measured the capasules of cast skins which had evidently shrunk somewhat. It is possible also that slight errors may have occurred in either set of measurements, due to the difficulties involved in measuring.

Growth and Moulting. The size of the body as a whole increases gradually and almost continuously from the time of hatching to the formation of the prepupa, but the size of the head capsule and anal shield increases only at the time of moulting. This is due to the fact that the covering of the body is elastic and permits a certain amount of expansion from growth at all times, while the head capsule and anal shield are rigid and therefore do not permit expansion except when the coat is very young and tender.

Just after hatching, the head and anal shield are as wide as or a little wider than the body, which is slender and covered by a loose-fitting skin. Feeding begins within a few hours and the larva grows longer and plumper. The skin becomes very tight as the body increases in size, but the head capsule remains the

Table 14.—The Stadia Periods of Active Larvae as Related to the Dates of Oviposition, 1928

Oviposition Date	Instar	Duration of Period (Days)			Number of Records
		Maximum	Minimum	Average	
Feb. 1-15	First	17	7	10.72	36
	Second	18	5	8.96	29
	Third	17	6	10.06	30
Feb. 16-29	First	11	7	9.00	6
	Second	8	5	6.66	3
	Third	19	11	14.33	3
Mar. 1-15	First	8	6	6.41	12
	Second	8	5	6.50	8
	Third	18	11	14.00	6
Mar. 16-31	First	15	7	10.00	22
	Second	9	5	6.50	18
	Third	19	5	10.46	15
Apr. 1-15	First	12	5	6.48	25
	Second	9	5	6.26	23
	Third	13	5	7.27	18
Apr. 16-30	First	11	5	7.13	22
	Second	8	3	4.95	21
	Third	14	4	7.57	19
May 1-15	First	7	5	5.61	26
	Second	9	3	5.17	23
	Third	14	5	6.30	23
May 16-31	First	7	5	6.00	20
	Second	6	3	4.12	16
	Third	11	4	5.71	14
June 1-15	First	5	3	3.92	38
	Second	8	3	4.13	37
	Third	16	5	7.77	31
June 16-30	First	6	4	4.65	32
	Second	13	3	4.52	23
	Third	15	6	8.80	10
July 1-15	First	7	4	4.48	37
	Second	8	3	5.41	31
	Third	17	3	6.76	26
July 16-31	First	7	3	4.22	40
	Second	9	2	3.75	32
	Third	11	4	5.79	24
Aug. 1-15	First	7	3	4.45	11
	Second	7	3	4.22	9
	Third	8	3	5.66	6
Total					825

same except for the development of a slightly darker color (Fig. 3). Finally a short rest period occurs, at the end of which the skin splits on the dorsal side near the anterior end, the head is withdrawn from the capsule, and the larva crawls out of the old skin. Wave-like contractions and expansions of the larva's body aid in slipping the old skin off as the larva moves forward. Feeding begins once more in a short time, and another moult occurs during the active period.

Table 15.—The Stadia Periods of Active Larvae, by Generations, 1928

Generation	Instar	Duration of Period (Days)			Number of Records
		Maximum	Minimum	Average	
First	First	17	5	8.58	123
	Second	18	3	6.83	102
	Third	19	4	9.46	91
Second	First	7	3	4.79	131
	Second	13	3	4.39	114
	Third	17	4	7.22	90
Third	First	7	3	4.38	73
	Second	9	2	3.92	57
	Third	11	3	5.84	44
Total					825

Prepupal Period. As has been previously stated, the prepupal period is a period of rest occuring during the latter part of the third instar. It corresponds to similar rest periods which were observed to occur just previous to the first two moults, the only visible difference being a difference in length of duration. The duration of the first two was only a few hours or days at most, while the duration of the prepupal rest period was from several days to more than two weeks.

The prepupal periods as related to the time of year in which they occurred are given in Table 17. This was a very variable period, the maximum duration for the two years being 16 days and the minimum 2. Early in 1927 the average periods were a little shorter than in 1928, but later in the year the comparable durations were exactly reversed.

Table 16.—Width of the Head Capsule

Stage	Width in Millimeters			Number of Records
	Maximum	Minimum	Average	
First Instar	.30	.25	.274	17
Second Instar	.415	.39	.402	13
Third Instar	.64	.58	.604	13
Pupa	1.35	1.20	1.261	6

The prepupal periods by generations are given in Table 18. The average period in 1927 varied from 6 to 8 days, and in 1928 from 4 to 8 days.

Table 17.—The Prepupal Period as Related to the Date of Oviposition, 1927 and 1928

	Duration of Period (Days)						Number of Larvae	
	Maximum		Minimum		Average			
Oviposition Date	1927	1928	1927	1928	1927	1928	1927	1928
Feb. 1-15	16	15	4	6	8.2	9.9	10	29
Feb. 16-29	6	8	5	7	5.6	7.6	3	3
Mar. 1-15		9		7		7.6		5
Mar. 16-31		10		5		7.3		13
Apr. 1-15		10		5		6.6		15
Apr. 16-30		10		4		6.3		17
May 1-15	7	8	4	4	5.3	5.7	3	20
May 16-31		7		4		4.7		13
June 1-15		13		4		6.0		23
June 16-30	8	8	4	3	6.0	5.0	2	8
July 1-15		8		3		4.6		18
July 16-31	6	9	6	3	6.0	4.7	1	11
Aug. 1-15		6		2		3.8		5
Total							19	180

The Pupal Period. At the end of the prepupal period, the short, thick, resting larva moults and enters the pupa stage. A greater increase in the size of the head capsule occurs following this moult than either of the previous ones. The average width of all individuals measured in 1928 increased from .604 to 1.262 mm. (Table 16).

Table 18.—The Prepupal Period, by Generations, 1927 and 1928

	Duration of Period (Days)						Number of Prepupae	
	Maximum		Minimum		Average			
Generation	1927	1928	1927	1928	1927	1928	1927	1928
First	16	15	4	4	7.6	7.9	13	82
Second	7	13	4	3	5.3	5.5	3	73
Third	8	9	4	2	6.0	4.3	3	25

While considerable variation occurred among different individuals, the average duration of pupal periods was fairly constant throughout the year in both 1927 and 1928 (Table 19). The maximum duration for the two years was 16 days and the minimum 3. The average periods at different times of year varied from 6 to 12 days.

The pupal periods by generations are shown in Table 20. The average duration for all generations during the two years was approximately one week.

The Total Developmental Period. The total developmental period consists of all stages from the egg to the adult. This period is fairly constant in length of duration among different individuals at a given time of year, but is quite variable at different times of year.

Table 19.—The Pupal Period as Related to the Date of Oviposition, 1927 and 1928

Oviposition Date	Duration of Period (Days)						Number of Pupae	
	Maximum		Minimum		Average			
	1927	1928	1927	1928	1927	1928	1927	1928
Feb. 1-15	9	15	6	9	8.0	12.0	10	26
Feb. 16-29	7	10	7	9	7.0	9.3	4	3
Mar. 1-15		10		8		9.0		4
Mar. 16-31		11		8		8.8		9
Apr. 1-15		10		6		7.4		10
Apr. 16-30		8		6		7.0		13
May 1-15	7	7	6	5	6.3	5.6	3	19
May 16-31		7		6		6.7		10
June 1-15		7		3		5.6		20
June 16-30	7	7	6	5	6.5	6.1	2	8
July 1-15		16		4		6.8		14
July 16-31	6	8	6	5	6.0	6.4	1	11
Aug. 1-15	6*	11	5*	6	5.7*	7.2	4*	5
Total							24	152

*1926 instead of 1927.

The developmental periods as related to the time of year in which they occurred are shown in Table 21. The maximum period of 87 days occurred in the spring of 1928, while the minimum period of 27 days occurred late in the summer of the same year. The average periods for the two years varied from 82 to 30, depending upon the time of the year and the temperature at which the stages developed.

Table 20.—The Pupal Period, by Generations, 1927 and 1928

Generation	Duration of Period (Days)						Number of Pupae	
	Maximum		Minimum		Average			
	1927	1928	1927	1928	1927	1928	1927	1928
First	9	15	6	6	7.7	9.5	14	65
Second	7	16	6	3	6.3	6.2	3	63
Third	7	12	5	5	6.0	6.7	7	24

The total developmental periods by generations are given for 1927 and 1928 in Table 22. The approximate average duration for the two years was for the first generation nine weeks, for the second generation five weeks, and for the third generation five weeks.

The Adult Period. The adult period varies greatly in length of duration. The maximum duration of the adult period in 1928 was 75 days for the first generation and 67 days for the second, while it was as great as 200 days for adults of the third generation that lived overwinter into the spring of 1929. The average duration of the adult period under normal conditions was not accurately determined due to a number of factors. Adults reared in the laboratory often emerged from the pupal cell in bad condition and died within a few days. Upon one or two occasions large numbers of adults were killed on hot days by the sun shining directly through the small glass vials in which they were confined and upon one occasion by the temperature dropping to 8 degrees F. Then too, some of the adults were collected from the field and their ages could not be determined. For these

Table 21.—The Total Developmental Period as Related to the Date of Oviposition, 1927 and 1928

Oviposition Date	Duration of Period (Days)						Number of Records	
	Maximum		Minimum		Average			
	1927	1928	1927	1928	1927	1928	1927	1928
Feb. 1-15	66	87	51	78	59.6	82.1	12	23
Feb. 16-29	57	72	56	70	56.5	71.3	4	3
Mar. 1-15		64		64		64.0		4
Mar. 16-31		64		55		59.8		9
Apr. 1-15		58		53		56.5		10
Apr. 16-30		53		44		47.0		13
May 1-15	36	49	33	37	34.5	39.5	2	20
May 16-31		36		34		34.7		10
June 1-15		44		33		36.0		21
June 16-30	39	44	32	32	35.5	36.5	2	8
July 1-15		42		27		33.8		14
July 16-31	31	35	31	29	31.0	32.5	1	11
Aug. 1-15	31*	37	30*	29	30.5*	33.0	4*	5
Total							25	151

*1926 instead of 1927.

reasons, this report does not give the normal average life of the adult. It appears, however, that the average duration of the adult period during the hot summer months does not exceed two months and is probably less than two, while the average duration during the cool fall, winter, and spring months may be from four to six months or more.

Table 22.—The Total Developmental Period, by Generations, 1927 and 1928

Generation	Duration of Period (Days)						Number of Records	
	Maximum		Minimum		Average			
	1927	1928	1927	1928	1927	1928	1927	1928
First	66	87	51	44	58.8	65.7	16	62
Second	36	49	33	31	34.5	36.9	2	67
Third	39	37	30	27	32.0	32.2	7	22

Females are more vigorous and live for a longer period than males. The average life of all known females in the laboratory during 1928 was 40.55 days as compared to 32.61 days for all known males. A higher percentage of females also live overwinter. Seventy per cent of all beetles collected in the field during the early spring of 1928 were known to be females (Table 23), while later in the year only about 25 per cent of the beetles were known to be females. It is possible, however, that a higher percentage of the individuals in each instance were females, since they were not determined by actual examination but by merely determining the number that deposited eggs.

Table 23—The Number and Per Cent of Known Females Among the Adults of the Different Generations, 1928

Number of Adults	Number of Females	Per Cent Females	Generation
51	36	70.5	Overwintered*
65	14	21.5	First**
67	20	29.8	Second**
23	6	26.1	Third**

*Collected from the field.
**Reared in the laboratory.

FLIGHT AND MIGRATION

Adults of the southern corn rootworm are fairly strong fliers that travel from place to place a great deal, especially during the summer months. The author has followed a beetle on the wing for more than 400 feet, and the beetle when last seen was flying at a height of about 15 feet above the ground. Sell (49) found that females could remain on the wing for longer periods than males and that either males or females which had been starved for several days could remain on the wing for longer periods than those which had recently fed. Beetles that had fasted for two to four weeks were able to remain on the wing for 30 or 40 minutes before becoming fatigued.

While adults have a tendency to congregate upon winter legumes at Auburn in the late winter and early spring months, they spread to many other plants as soon as the tender foliage appears. There is considerable traveling to and away from the legume field as well as from plant to plant on warm days even in the early spring. The amount of traveling or migration apparently increases as more food plants become available. In July, 1916, Sell released 591 beetles marked on the elytra with a dash of India Ink. Only eight of this number could be found the following day. Upon another occasion he observed 30 beetles spending the night on a small number of plants, but none of them returned to their respective plants the following night. These data indicate that migration among twelve-spotted cucumber beetles is very great and that they are not influenced greatly by a "homing instinct."

INSECTS MISTAKEN FOR D. 12-PUNCTATA

The adult of the southern corn rootworm is frequently called a ladybird by laymen. Specifically it has been confused with the Mexican bean beetle (Epilachna corrupta). There is, however, very little resemblance between the two forms. The belted bean beetle (D. balteata) is sometimes mistaken for D. 12-

punctata by those fairly familiar with insects, but it may be easily distinguished by its smaller size and bright green color with three distinct yellow bands across the elytra and a fourth indistinct one at the tips of the elytra. The bean leaf beetle (Ceratoma trifurcata) is also sometimes mistaken for D. 12-punctata. It is rather variable in color, but can be distinguished by its smaller size and yellow or reddish color, usually marked on the elytra with four centrally located, prominent, angular, black spots and other less prominent black markings.

Damage caused by the striped cucumber beetle (D. vittata) as well as D. balteata and C. trifurcata may be confused with that of D. 12-punctata. In fact it is practically impossible to distinguish between injury produced by the four different forms. Injury produced by E. corrupta is, on the other hand, easily distinguished from D. 12-punctata injury by the network of tissues which remains.

The larvae of D. soror, balteata, longicornis, and vittata are according to Boeving (10) almost identical, in general aspects and most of the anatomical details, with D. 12-punctata. Since all of these forms except vittata are known to feed upon the roots of corn, there might easily arise, in certain sections, confusion as to which form was present. In Alabama, however, **soror** and **longicornis** do not occur and **balteata** is not present in sufficient numbers at corn planting time to cause much infestation except perhaps in the extreme southern part of the state. It is doubtful as to whether or not injury occurs there.

Injury caused by the corn wireworms (Melanotus cribulosus and others), the corn earworm (Chloridea obsoleta), several species of cutworms, and the roughheaded corn-stalk beetle (Eutheola rugiceps) have been mistaken in Alabama for southern corn rootworm injury. The wireworm produces injury closely resembling the injury of D. 12-punctata larvae, but by digging up the plant it can be easily distinguished by its hard, shining brown body and terminal mandibles. The rough-headed corn-stalk beetles eat holes in the base of the stalks. The plants attacked, however, are usually larger than those attacked by the southern corn rootworm. The corn earworm and cutworm injury is to the foliage above the ground. In case of the cutworm, the plant is usually cut in two at the surface of the ground or a little above.

PREVENTION AND CONTROL

Natural Control

Enemies. A number of natural enemies aid in the control of both adult and larval stages of D. 12-punctata, but the adults are subject to more attacks from enemies than the larvae.

Several common species of birds feed upon the adults. Webster (68) reported a list of 24 species of birds found by the Biological Survey to feed upon D. 12-punctata adults. The list is as follows: Bobwhite (Colinus virginianus), scaled quail

(Callipepla squamata), California quail (Lophortyx californicus), prairie chicken (Tympanuchus americanus), wild turkey (Meleagris gallopavo), yellow-bellied sapsucker (Sphyrapicus varius), red-headed woodpecker (Melanerpes erythrocephalus), nighthawk (Chordeiles virginianus), scissor-tailer flycatcher (Muscivora forficata), kingbird (Tyrannus tyrannus), phoebe (Sayornis phoebe), wood pewee (Myiochanes virens), western flycatcher (Empidonax difficilis), Acadian flycatcher (Empidonax virescens), Traill's flycatcher (Empidonax trailli), least flycatcher (Empidonax minimus), red-winged blackbird (Agelaius phoeniceus), meadowlark (Sturnella magna), Bullock's oriole (Icterus bullocki), cardinal (Cardinalis cardinalis), rose-breasted grosbeak (Zamelodia ludoviciana), cliff swallow (Petrochelidon lunifrons), white-eyed vireo (Vireo griseus), robin (Planesticus migratorius). The bobwhite apparently eats a larger number of beetles than any other bird in the list. Upon one occasion, 12 beetles were found in the stomach of one bobwhite.

In addition to its bird enemies, the adult of the southern corn rootworm has a rather dstructive parasitic enemy in the form of a tachinid fly (Celatoria diabroticae), the larva of which develops within the beetle and causes its death. As many as 20 per cent of the D. 12-punctata adults may be infested in the latter part of January, but the percentage is much lower later in the year (Table 1).

The larva of the southern corn rootworm is sometimes attacked and killed by ants. Upon two occasions in 1928, they found their way into the rearing vials in the laboratory and produced havoc among the half-grown larvae there. It is doubtful if they are of very great value in reducing the number of larvae in the field, but they have been observed several times associated with infested corn in the field and in a few rare instances actually feeding upon larvae. The species of ants attacking the larvae were not determined.

Webster (68) expressed the belief that the larvae of a click-beetle (Dasterius elegans) feed upon southern corn rootworms, but the author is rather inclined to discredit the correctness of this belief.

Climatic Conditions. The developmental stages of D. 12-punctata are affected to a greater degree by unfavorable climatic conditions than the adult, but both forms are affected to a considerable extent.

Adults cannot withstand extremely low temperatures. Tests to determine the percentage of beetles living through the winter from year to year were not conducted, but beetles were confined in the laboratory during the winter months of two consecutive years. On January 1, 1928, more than fifty adults were killed in the laboratory when the temperature dropped to 8 degrees F. Not a single one survived. It is true that these beetles were not as well protected as those hibernating in the field, but adults in the field were decidedly fewer in number during the spring of 1928 than during the spring of either 1927 or 1929. There was also a much lower infestation of corn seedlings in 1928, although the soil was fairly moist throughout most of the spring.

Hot, dry weather is detrimental to all the developmental stages. The high temperatures within themselves are not detrimental, but they are inducive to a dry environment which is fatal. In the laboratory, eggs placed on dry cotton and exposed to the drying effect of the sun collapsed within a few days and soon disintegrated. Under the same conditions, larvae quickly died from desiccation. In the field, serious injury to corn was observed only on low lands or uplands containing a fair amount of soil moisture. Consequently, one needs to expect little injury to corn during periods of drouth.

Preventing Larval Injury to Corn

The problem of how to prevent larval injury to corn is not a new one. It is viewed from a new angle, however, in connection with growing corn after winter legumes, a practice that is annually becoming more common in Alabama. The adults of the southern corn rootworm are attracted to the legume plants during the late winter and early spring months. They feed upon the foliage and deposit their eggs in the soil. After hatching, the young larvae feed upon the roots and nodules of the legumes until the soil is turned and the corn planted, at which time they attack the young corn seedlings. Large numbers of eggs may continue to hatch for several days after the legume is turned.

Since the legume crop which immediately precedes the corn serves to collect the insects and make certain the presence of larvae during the time of year the first generation is developing, the problem resolves itself into one of determining when to turn the legume and when to plant the corn so that the minimum number of first-generation larvae will be present. In order to be certain that the minimum is present, it is necessary to wait until most of the first-generation larvae have passed the feeding stage or to destroy the food plants of both adults and larvae and keep the land free from them for a period of such length that few larvae will be present when the corn is planted. The life-history studies, previously discussed, were designed partly for the purpose of determining when the maximum and minimum number of larvae would be present, while field experiments were conducted to determine the effect of destroying the food plants previous to planting the corn at different times of the planting season. The field work was also for the purpose of supplementing the life-history work and determining in a practical way when the greatest and least amount of injury actually occurs in the field.

Method of Procedure. The experimental area in the field was divided into three sections. Each section was in turn subdivided into two, five-plot series (Fig. 11). Winter legumes were grown on one series of plots, in each section, while the other series was used as a check. The dates of turning varied slightly from year to year due to varying weather conditions, but at the beginning of the experiment the following dates were set as the approximate dates of turning: Section I, March 15; Section II, April 1; and Section III. April 15. The turnings were made at approximately these dates in both 1927 and 1929, but were made almost two weeks later than these dates in 1928 due to the late cool weather and scanty growth of legumes. On each section, one plot of corn was planted the day following the turning of that section and one plot each succeeding week until five plantings were made. The number of grains planted on each plot was recorded, the per cent coming up calculated, and the amount of infestation by southern corn rootworms determined. Germination tests were also run in the laboratory.

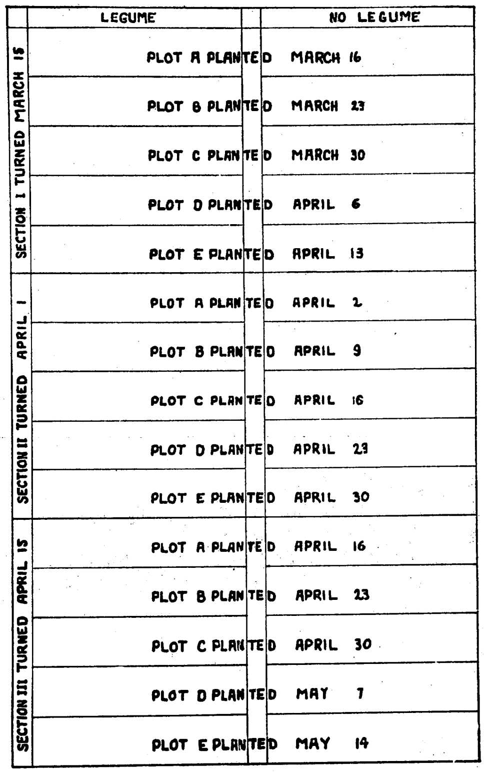

Fig. 11.—Diagram of the Experimental Area with the Approximate Dates of Turning and Planting.

In determining the infestation, careful observations of all corn seedlings were made at one- to four-day intervals. If a plant showed symptoms of infestation it was dug up and the infestation verified or disproved by the presence or absence of injury to the roots. The larvae themselves were usually found upon infested plants. All infested plants were probably not determined by this method, as injury is sometimes of such a mild nature that symptoms are not plainly visible. It was assumed, however, in this experiment that an infestation which was not severe enough to produce a plainly visible effect upon the plant was not of much consequence and should therefore be ignored.

Results Obtained. The injury to corn was much greater on the legume plots than on the check plots in 1927, 1928, and 1929. It was also much greater on both series of plots in 1927 and 1929 than in 1928, the maximum of 92 per cent infestation being reached in 1929. Table 24 gives the per cent of infestation on all plots for the three years.

In 1927 the greatest amount of injury occurred in the corn of Section I (turned March 15). The infestation for the first three plantings ranged from 27 to 63 per cent on the legume plots and from 21 to 30 on the check plots, while very little infestation occurred on the fourth and fifth plantings (Fig. 12). The relatively high infestation on the early check plots was probably due to a small amount of volunteer vetch growing on the check at the time of turning. Much less injury occurred on Section II (turned April 1) although the infestation on the legume plots for the first and second plantings was 25 and 10 per cent respectively. Little or no infestation occurred on the other plots of this section. The corn on Section III (turned April 15) was practically uninjured by southern corn rootworms.

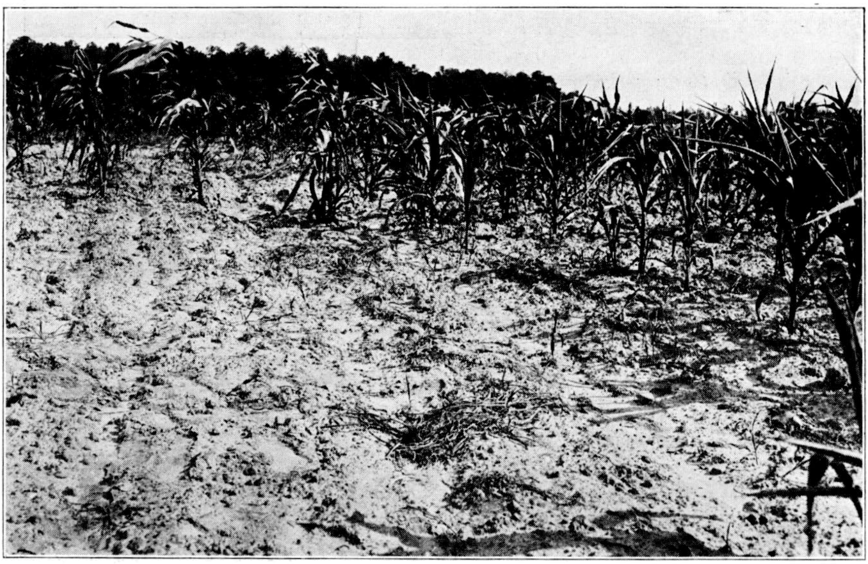

Fig. 12.—Corn following Winter Legumes, 1927. Land turned March 16; corn, left and front, planted two weeks later, extreme right three weeks later.

The corn on all plots escaped serious injury in 1928 although the soil was fairly moist during the corn-planting season. The maximum infestations were 9, 3, and 0.6 per cent respectively for Sections I, II, and III. This low percentage of infestation was probably caused by a high mortality of adults during the severe winter which had preceded.

The greatest amount of injury occurred in 1929. The preceding winter had been unusually mild and the soil moisture throughout the first half of the year was much above normal, making conditions for southern corn rootworms ideal. Early in the year the infestation was almost complete on some of the legume plots, many of the stalks being attacked by from two to five larvae. On Section I (turned March 15) the infestation for the first three plantings ranged from 35 to 92 per cent on the legume plots and from 5 to 19 per cent on the check plots (Figs. 13 and 14). While the infestations were much less for the last two turnings it is doubtful if the 5.1 per cent, listed in Table 24 for the fourth planting, represents the total injury caused by rootworms to that plot, since only 34 per cent of the corn planted came up on the legume plot as compared to 68 per cent on the check plot. On Section II (turned April 1) the infestation for the first three plantings ranged from 11 to 65 per cent on the legume plots and from 1 to 16 per cent on the check plots. No infestation occurred on the last two plantings. The only infestation occurring on Section III (turned April 15) was in corn of the first two plantings. An infestation of 15 and 11 per cent respectively occurred on the legume plots there.

Fig. 13.—Corn Following Winter Legumes, 1929. Land turned March 21, corn planted two weeks later.

Comparison With Other Work. No reports have been published on southern corn rootworm control in relation to growing corn after winter legumes, but several investigators have published results of studies in relation to ordinary farm practices and especially in relation to growing corn on bottom lands. These reports in a general way agree with results obtained at Auburn in that they advocate late planting to avoid injury. Thomas (60) recommends that corn be planted in lower South Carolina May 5, in middle South Carolina May 12, and in the Piedmont region May 19.

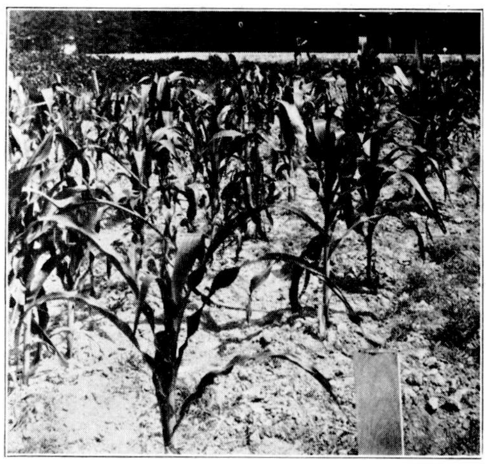

Fig. 14.—Corn on Check Plot, 1929. Land turned March 21, corn planted two weeks later.

Table 24—The Per Cent Infestation on all Plots, 1927, 1928, and 1929

		Per Cent Infestation					
		1927		1928		1929	
Date* Turned	Date* Planted	Legume Plot	Check Plot	Legume Plot	Check Plot	Legume Plot	Check Plot
Mar. 15	Mar. 16	54.3	21.0	6.8	3.8	35.4	5.7
Mar. 15	Mar. 23	26.9	14.5	7.5	1.2	92.4	19.2
Mar. 15	Mar. 30	63.2	30.0	9.0	6.5	62.5	8.9
Mar. 15	Apr. 6	6.4	2.6	1.2	6.1	5.1‡	2.1
Mar. 15	Apr. 13	0.4	0.0	2.4	1.0	1.2	2.4
Apr. 1	Apr. 2	25.8	1.6	3.1	1.2	65.6	16.3
Apr. 1	Apr. 9	10.2	1.8	0.0	2.6	42.1	9.0
Apr. 1	Apr. 16	0.4	0.0	0.9	0.0	11.1	1.1
Apr. 1	Apr. 23	1.0	0.0	0.7	0.0	0.0	0.0
Apr. 1	Apr. 30	0.0	0.0	0.0	0.8	0.0	0.0
Apr. 15	Apr. 16	1.6	0.0	0.6	0.0	15.3	1.1
Apr. 15	Apr. 23	0.0	0.0	0.0	0.0	11.1	0.0
Apr. 15	Apr. 30	1.6	0.0	0.0	0.0	0.0	0.0
Apr. 15	May 7	1.2	1.2	0.0	0.0	0.0	0.0
Apr. 15	May 14	0.4	0.0	0.0	0.0	0.0	0.0

*Dates only approximate. Weather conditions from year to year necessitated slight departures from these dates.

‡Injury was probably more serious than the percentage indicates.

Luginbill (34) recommends that corn in the latitude of southern North Carolina and northern South Carolina be planted from May 10 to 20, in the latitude of southern South Carolina and central Georgia May 1 to 10, and in southern Georgia and northern Florida April 20 to May 1. Bradley (8) reports little or no injury to corn in Louisiana planted during the first part of March, increasing injury the last of March and first of April, and little or no injury again toward the last of April. The highest percentage of infestation occurred in corn planted April 8. Isely (31) recommends that corn be planted on bottom lands in Arkansas about June 1.

Effect of Crop Rotation. Crop rotation has been commonly recommended (11, 14, 16, 34, 44, 47) in the past as a method of southern corn rootworm control in general farm practices but more recent observations and investigations indicate that crop rotation is of little or no value except in so far as the crop **immediately** preceding corn is concerned. Webster (65) reported 75 per cent infestation of two fields of corn which had followed cotton in Texas. Garman (23) and Isely (31) concluded that the crop grown in a field the preceding year has little to do with southern corn rootworm injury to corn. With the information now available concerning the adult's habits of flight, feeding, and oviposition, it becomes obvious that the crop grown in a given field one year cannot seriously affect the amount of damage occurring to corn in that field the following year. Field observations at Auburn bear witness to this fact, since as high as 92 per cent infestation occurred in 1929 to corn in an area which had grown only cotton the previous year. No corn had grown in the immediate vicinity of the area.

Conclusion and Recommendations. The Agronomy Department at Auburn has found that corn following legumes turned from April 1 to 15, or a little later produces larger yields than corn following legumes turned previous to April 1 (6). This, of course, is based upon the assumption that the southern corn rootworm is not a factor.

Since the life-history work has shown larvae to be most numerous during the latter part of March and the first part of April (Figs. 7, 8, and 10), and the field work has shown the greatest infestation in corn to occur following the turning of legumes March 15 (Table 24), the legumes should not be turned previous to April 1. The data obtained indicate that in the latitude of Auburn corn may be safely planted three weeks after turning legumes April 1, while it may be planted two weeks after turning legumes April 15. Considered from all angles, the turning on April 15 is probably more desirable, but in either case the land should be thoroughly disked after turning in order to destroy the larvae's source of food. The legumes should not be allowed to grow much later than April 15 as an infestation of corn earworms may occur.

Less data is available to indicate when corn on bottom land should be planted, but Figs. 7, 8, and 10 show the first generation larvae disappearing about the first of May and the second generation larvae beginning to appear about the middle of May. Since little or no infestation occurred on the check plots during the period between generations, it appears that corn on bottom land (or any other susceptible area not associated with winter legumes) should be planted early in May of a normal year. The soil should be turned several weeks previous to the planting and kept free of vegetation until the corn is planted. Isely recommends clean cultivation for one month previous to planting.

In the truck growing regions of South Alabama, the important factor is the early production of corn for the early markets and late planting to avoid rootworm injury cannot be practiced. Susceptible areas should, therefore, be kept cleanly cultivated for a period of perhaps four to six weeks previous to the planting of corn.

Planting the corn thickly in the drill and thinning it out when it has passed the seedling stage is a practice that may also be adopted to advantage under certain conditions.

Dusting to Control Adults

Since adults of the southern corn rootworm are sometimes rather serious pests of curcubits, beans, and other garden crops, experimental work was done in 1928 to determine the most effective materials to use in poisoning the adults.

Method of Procedure. One hundred beetles, collected from the field in the late afternoon of June 7 and early morning of June 8, were placed in 10 screen-wire cages, 10 beetles to a cage. These beetles had received neither food nor water for an average period of about 12 hours previous to the time they were placed in the cages in the early afternoon of June 8. Cheese cloth was spread upon the ground in the greenhouse and the bottomless cages were placed upon the cheese cloth. The cages, cheese cloth, and soil were dry. A young bean plant with only two well-developed leaves was placed in each cage except the two indicated in Table 25. The plants were growing in small pots of moist soil. Since this was the only moisture in the cage, a similar pot of moist soil was placed in the cage containing no food in order that the moisture factor might be uniform. Enough water was added to the soil in all pots each day to keep it moist.

Seven different combinations of dusting materials were used in eight cages. The other two cages were used as checks, one with food present and one without food. In addition to the six different materials used in as many cages, the same material, namely undiluted calcium arsenate, was used in two cages. One of these cages contained food; the other was without food. The dusts were applied with a hand dust gun after the beans had been placed in the cages but before the beetles had been released there.

The temperature of the green house was fairly constant during the experiment, ranging from 78 to 92 degrees F., with an average of about 85 degrees.

Results Obtained. Immediately after being released from the vials into the cages, there occurred a short period of straightening out of wings and cleaning of legs and antennae among the beetles of all cages. Continued observations, however, revealed the fact that much more cleaning of tarsi and tarsal claws occurred among the individuals of the dusted cages than among those of the check cages. This was attributed to an attempt on the part of the beetles to clean off the dust picked up in crawling over the cheese cloth, cages, and plants. Just which dusts caused the most irritation and consequently the greatest amount of tarsal cleaning was not determined.

The per cent of mortality after exposure to poison is shown in Table 25. The undiluted dusts of calcium arsenate, lead arsenate, and sodium fluosilicate caused 100 per cent mortality at the end of 24 hours. These same dusts diluted one to nine with hydrated lime were much slower in action, but with the exception of sodium fluosilicate caused complete killing at the end of 40 hours. Sodium fluosilicate required slightly more than 40 hours.

A mixture composed of calcium arsenate, one part; sulphur, one part; and hydrated lime, four parts, was slow in action, like the dusts just discussed, but caused complete killing at the end of 40 hours.

The per cent of mortality after exposure to undiluted calcium arsenate with and without food is shown in Table 26. It will be noted that all beetles were dead in the cages containing no food at the end of 18 hours and in the cages containing food at the end of 24 hours, while no death occurred in either of the checks inside of 48 hours.

No burning occurred on any of the bean plants, although it is well known that the arsenicals used will often burn beans in the field. The dry condition of the foliage is probably the factor responsible for the complete absence of burning.

Table 25.—Per Cent Mortality After Exposure to Poison

Poison Used*	Hours Exposed and Mortality			
	18	24	30	40
	Per Cent	Per Cent	Per Cent	Per Cent
No. 1	90	100	100	100
No. 2	60	70	90	100
No. 3	60	100	100	100
No. 4	70	80	90	100
No. 5	70	100	100	100
No. 6	20	50	70	90
No. 7	00	50	80	100
Check	00	00	00	000
No. 8**	100	100	100	100
Check‡	00	00	00	00

*Poison Used:
No. 1—Calcium arsenate, undiluted.
No. 2—Calcium arsenate 1 part, Hydrated lime 9 parts.
No. 3—Lead arsenate, undiluted.
No. 4—Lead arsenate 1 part, Hydrated lime 9 parts.
No. 5—Sodium fluosilicate, undiluted.
No. 6—Sodium fluosilicate 1 part, Hydrated lime 9 parts.
No. 7—Calcium arsenate 1 part, Sulphur 1 part, Hydrated lime 4 parts.
No. 8**—Calcium arsenate, undiluted. No food was present.
Check‡—No food was present.
Food was present at all times in all tests except the two specified above.

Table 26.—Per Cent Mortality After Exposure to Undiluted Calcium Arsenate With and Without Food

Treatment	Food	Hours Exposed and Mortality						
		4	18	24	30	40	48	66
		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Poisoned	Bean Leaves	50	90	100	100	100	100	100
Poisoned	None	50	100	100	100	100	100	100
Not Poisoned	Bean Leaves	00	00	00	00	00	00	10
Not Poisoned	None	00	00	00	00	00	30	70

Comparison With Other Work. Isely recommends the use of sodium fluosilicate diluted 1 to 3 with hydrated lime for the control of adults. He found that arsenical dusts repelled them. Marcovitch (35) found that sodium fluosilicate was very satisfactory in controlling a closely related species of beetles, D. vittata. He also found that this dust was more toxic to insects and produced less burning to plants than arsenicals. Practically no burning was observed when it was applied to dry foilage. When applied to damp or wet foilage, sodium fluosilicate produced less burning than a large number of other materials including hydrated lime. Upon several occasions he observed hydrated lime, unmixed with other substances, and hydrated lime mixed with sodium fluosilicate causing much more severe burning than sodium fluosilicate undiluted. It is not the purpose of the writer to dispute the correctness of Marcovitch's observations, but considerably different results were obtained at Auburn. Sodium fluosilicate dust, applied to a large number of garden plants, was effective in controlling various species of insects, including D. 12-punctata, and produced comparatively little burning when applied to dry foilage, but without exception produced less burning when diluted with hydrated lime than when applied undiluted.

In connection with methods by which insects get a lethal dose of poison, it is interesting to note the findings of Grossman (28A). He found that the Mexican boll weevil (Anthonomus grandis) obtained enough calcium arsenate to cause the death of the beetle, not primarily by feeding, but by resting the end of the snout upon the dust-covered surface of the cotton plant. The adult of the southern corn rootworm does not pick up the poison in exactly the same manner, but as has already been pointed out, it is not necessary for the beetle to feed in order to take the poison into its body (Table 26).

Conclusion and Recommendations. Adults may be controlled by dusting the affected plants with calcium arsenate, lead arsenate, or sodium fluosilicate. These dusts may be diluted with hydrated lime or with flour, but the data obtained indicate that the dilution should be less than 1 to 9. Since sodium fluosilicate produces less injury to foilage than arsenicals and does not repel the adults, it should be used in preference to the others. Isely recommends that it be diluted with hydrated lime in the proportion of one part of the insecticide to three parts of lime. This dilution should be very satisfactory for most plants. If plants are especially susceptible to lime-burning, however, it might be well to substitute ordinary flour for lime.

The dust should be applied with a suitable dust gun to the dry foliage. This gives an even distribution of dust particles over the entire plant and reduces the possibilities of burning. The dry condition of the dust also makes it easier for the beetles to pick up the dust with the tarsi while crawling over the plants. Since dust picked up in this manner is cleaned off with the mandibles and a lethal dose of poison may be swallowed by the insect, it is very desirable that the aforementioned condition exists.

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SUMMARY

1.—The southern corn rootworm is a serious pest of corn planted after winter legumes or on bottom lands. The adult, known as the twelve spotted cucumber beetle, is a pest of less importance upon cucurbits, melon crops, and flowers.

2.—Three complete generations and a partial fourth occur annually in Alabama. Adults of the third generation overwinter and begin oviposition during the latter part of January. Oviposition is practically continuous throughout the spring and summer to the middle of October.

3.—There is a high correlation between the temperature and the rate of development. The average number of days required for development from egg to adult in 1928 decreased from 81 when the mean temperature was 55 degrees F. (eggs deposited February 3) to 33 when the mean temperature was 79 degrees F. (eggs deposited August 5). The average number of days required in development for individuals of the first, second, and third generations was 58, 34, and 32 respectively in 1927 and 65, 36, and 32 respectively in 1928.

4.—A dry environment is fatal to the immature stages. A cold environment (10 degrees F. or below) causes a high mortality of adults.

5.—Adults are parasitized by a tachinid fly. This parasite is of considerable importance in reducing the number of adults in the late winter and early spring months, but it is of little importance during the hot summer months.

6.—The most serious injury to corn is produced by half-grown to mature larvae attacking the young seedlings. In most cases these larvae are older than the corn attacked.

7.—Adults congregate upon winter legumes and deposit their eggs in the soil. The larvae emerge from the eggs and feed upon the roots and nodules of the legumes and the roots of wildgrasses until the soil is turned and the corn, which in common practice is planted after the legume, germinates, at which time they attack the young plants. Newly-hatched larvae also attack the seedlings, but do less damage than the older ones.

8.—The data in this report indicate that winter legumes preceding corn in the latitude of Auburn should not be turned before April 1 of a normal year. If legumes are turned April 1, it is unsafe to plant corn within three weeks from the date of turning. If legumes are turned April 15, it is unsafe (but to a lesser extent) to plant corn within two weeks from the date of turning. In either case the land should be thoroughly disked or harrowed after turning to destroy the larvae's supply of food.

9.—The data in this report indicate further that corn grown on damp bottom lands, or any other susceptible areas not associated with legumes, should be planted about May 1 of a normal year. The soil should be turned

several weeks (3 to 5) previous to planting and, by light cultivations, kept free of host plants.

10.—Crop rotation is not an effective control measure.

11.—Adults of the southern corn rootworm may obtain a lethal dose of poison by using their mandibles to clean off the dust picked up by the tarsi while crawling over the dust-covered surface of a plant. Sodium fluosilicate diluted with hydrated lime in the proportion of 1 to 3 appears to be the most satisfactory material to use in controlling adults.

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