BULLETIN No. 186 SEPTEMBER, 1915

ALABAMA

Agricultural Experiment Station

OF THE

Alabama Polytechnic Institute

AUBURN

The Grass Worm

or

Fall Army Worm

By

W. E. Hinds and J. A. Dew

Montgomery, Ala.
The Paragon Press.
1915

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The Grass Worm or Fall Army Worm

(*Laphygma frugiperda, S. A.*)

By W. E. Hinds and J. A. Dew.

INTRODUCTION.

This common caterpillar pest appeared abundantly in southern Alabama early in the spring of 1912 under such conditions as to attract general attention. There were indications that a general spread of the species might be expected throughout the State and adjoining states. An examination of the literature regarding this species showed that although much was known about it there were very many points relative to its life history and regarding methods for its control about which very little was known. The frequent occurrence and the vast economic importance of this pest seemed to justify an effort to gain additional information about it.

Accordingly in May, 1912, Mr. J. A. Dew, Field Assistant in the Department of Entomology at the Alabama Experiment Station, was stationed in southern Alabama to make a special study of the grass worm under the direction of the Entomologist with the expectation that the work should be continued through the season. While other members of the staff were at times engaged in making observations on the same species, by far the major part of the field records upon which this publication is based were made by Mr. Dew. (a)

Unfortunately the funds available for use in publication would not permit of the immediate publication of the results of the work. Meantime Mr. Dew severed connection with the Department and it has therefore devolved upon the Entomologist to put the matter into form for publication. With the observations made by Mr. Dew have been incorporated such additional material as has been accumulated up to date in the Department. It should be understood that the statements made herein apply to conditions existing in southern Alabama but hold good also for other portions of the Gulf Coast having similar climatic conditions.

The species appeared in small numbers only and in few localities in Alabama in 1913 and no complaint of it was received at the Experiment Station in 1914. In 1915, however,

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(a) A resumé of Mr. Dew's observations was published by him in the Journal of Economic Entomology, Vol. 6, No. 4, (August, 1913), pp. 361-366.

it appeared to be quite widely distributed before the end of July throughout the State and in many other Southern States.

ORIGIN AND DISTRIBUTION.

The grass worm seems to be a native of the Americas and may have originated in the Gulf States. The accounts of the distribution according to Chittenden, (Bulletin No. 29 of the Bureau of Entomology of the U. S. Department of Agriculture), show that the species has been found from Canada to Florida and from Colorado and Montana to the Atlantic Ocean. The species is also common in Cuba, Brazil, Jamaica and Barbadoes.

HISTORY.

The grass worm was first described in 1797 by Smith and Abbot in their "Natural History of the Lepidopterous Insects of Georgia." At that time the species was known as an enemy of young, growing corn, feeding deep down in the bud and also attacking other grains and grasses. The grass worm attracted little attention after 1797 until in 1845 it was reported as causing serious damage to fields of grass, corn, sugar cane and rice in Florida. Since 1845 partial destruction of the same crops has occurred frequently. Among the outbreaks recorded are: 1854 and 1855 in Georgia; 1866 in Kansas; 1868 in Arkansas, Missouri and generally in the upper Mississippi Valley; 1870 in Kansas, Missouri and Illinois; 1872, another outbreak in Georgia; 1874 Alabama, Georgia and South Carolina; 1881 Georgia and South Carolina; 1884 widespread infestation causing serious loss in the upper Mississippi Valley; 1892 overflowed lands of Louisiana; 1896-97 ravages of fields in Florida, Georgia, South Carolina, North Carolina and Virginia.

In the year 1899 occurred the heaviest infestation and the most general distribution recorded up to that time. Specimens were found from New York to Colorado and southward, including all of the cotton growing states. The following years, 1900 and 1901, brought only light infestations scattered locally over the above mentioned territory. Slight injury was recorded on overflowed bottom lands in Southern Alabama in the fall of

1906 and in the late fall of 1911 the pest was present in considerable numbers over this same territory. Data collected during 1912 indicates that large numbers of grass worms were present in Alabama during the late fall of 1911 feeding upon Johnson grass in the bottom lands and on alfalfa and cut over hay fields.

This survey of grass worm occurrence brings us to the season of 1912 during which the studies herein reported were principally made.

CLOSELY RELATED SPECIES.

The moth, (*Laphygma frugiperda,* S. & A.) is a member of the family Noctuidae, or night flyers. This is a large family and includes several of our most injurious caterpillar pests. Among these are the common cutworms of the lawn and garden, the corn ear worm (*Heliothis obsoleta,* Fab.) and the regular army worm, (*Heliophila* (*Leucania*) *unipuncta, Haworth*). Both of these species exhibit habits which are shown also to a certain extent by the grass worm.

COMMON NAMES.

On account of the large number of its food plants and the variations in its methods of feeding, etc., a large number of common names has been applied to this species, probably more than to any other native pest. The first name proposed (Smith and Abbot) was "corn bud worm" from the nature of its injury. During the outbreak in 1854-55, the name "grass worm" or "grass caterpillar" became common because grass forms its principal food plant. In the seventies farmers referred to the pest as the "fall army worm" on account of the fact that the species sometimes assumed the army habit of traveling at that season of the year. In more recent times this species has been known as the "wheat cut worm," "army cut worm," "Southern grass worm," "army worm," "corn worm," "grass army worm," "alfalfa worm," and "fall army worm." In the Barbadoes it is an annual pest and is there called the "corn ear worm" from the nature of the injury which it inflicts most commonly. The "grass worm" is perhaps the best common name that can be applied because it is undoubtedly true that grasses are the favorite food of the species The name "fall army worm" could also be applied as the pest rarely reaches serious proportions until this season of the year.

FOOD PLANTS.

From the earliest records up to the present time, the grass worms or fall army worms have shown that the plants of the grass family are their favorite food. Their feeding, however, is not confined to the grasses alone, the grains and nearly all other southern field crops are injured at times. During the season of 1912 a careful study was made of the food plants attacked in the State of Alabama and these are listed below somewhat in the order of apparent preference by the worms: crab grass, Bermuda grass, blue grass, Johnson grass, etc., corn foliage in the bud and grain in the ear as it is maturing; sugar cane in the bud and the tender leaves; alfalfa, sorghum, millet; kafir corn, rice, oats, wheat, cow peas, sweet potatoes, velvet beans, soy beans, snap beans, peanuts, clovers, buckwheat, cotton, tomatoes, Irish potatoes, cabbage, beets, bell peppers, turnips, rutabagas, spinach, strawberry, tobacco, pecan and satsuma orange foliage, cockle burrs, cucumber, and common night-shades.

The only plants observed upon which no larvae were ever seen feeding in 1912 were those of the curcurbit family as watermelons, squash, cucumber, pumpkin, etc. Frequently it was noticed that in fields where the worms had stripped the corn, grass and even cockle burrs, the pumpkins and watermelon vines in the same fields were left untouched. However, worms have been fed to maturity on cucumber leaves and have fed a little upon waltermelon foliage while kept in confinement.

The fact that the worms are able to sustain life upon such a large variety of food plants, together with the fact that the methods of feeding are so varied makes the control of the pest a difficult matter. The control method to be used must necessarily be adapted according to the location and manner of the injury.

FEEDING HABITS.

Grass worms feed for the most part at night. They may feed at any time during the day in case the weather remains cloudy. When food is abundant so that they are fully fed, most of the worms hide under clods of dirt or other shelter, especially during the heat of the day. When food becomes scarce, however, the worms are less strongly influenced by light and heat but impelled by hunger alone they seek for food, crawling rapidly from place to place. At such times they may kill and eat one

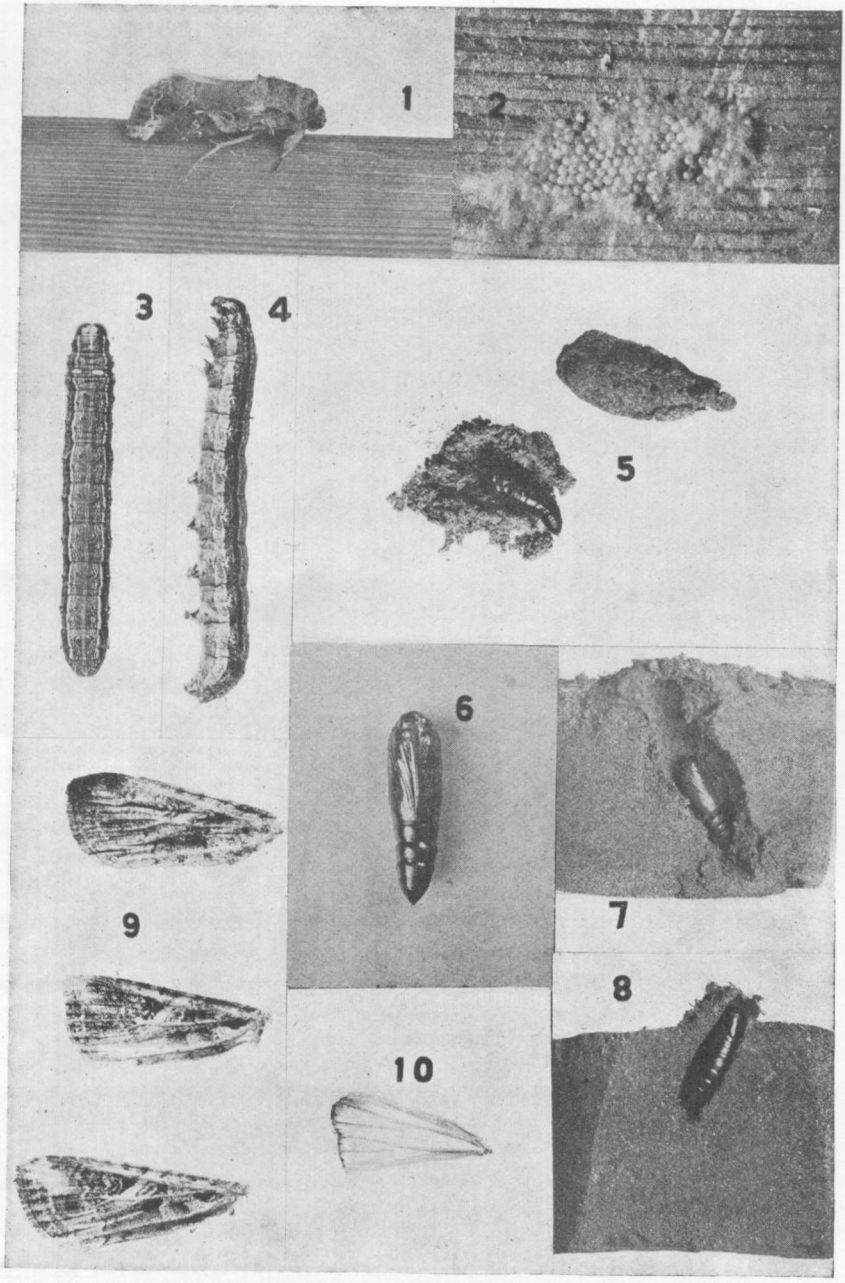


PLATE I. GRASS WORM STAGES AND CHARACTERS.

Fig. 1, Adult; fig. 2, egg cluster; fig. 3, worm nearly full-grown with two eggs of a parasite attached back of its head; fig. 4, full-grown worm, side view; fig. 5, pupal cells removed from ground; fig. 6, pupa isolated, ventral view; fig. 7, pupal cell in medium soft soil; fig. 8, pupal cell in stiff clay soil; fig. 9, three front wings showing variations in markings; fig. 10, hind wing. Figs. 5, 7 and 8 natural size, others enlarged one-half. All original.

(Fig. 1)

(Fig. II)

PLATE II. GRASS WORM WORK IN THE FIELD.

Fig. 1, Late planted corn entirely destroyed, Prattville, Ala.; fig. 2, heavy growth of crab grass and Johnson grass destroyed (note trash on ground). Original.

another. The cannibalistic tendency is strongly marked where the worms are brought into close contact and they devour other species of cut worms even more readily than they do one another. During the first three larval stages they usually feed upon the lower surface of leaves leaving the epidermis intact. This process is called "skeletonizing." In later stages they devour the entire leaf tissue. (See Pl. 4, fig. 1).

NATURE OF INJURY.

The injury wrought by the grass worm is often quite different upon different food plants and varies even with the age of the plants as well as with the age of the worms. For instance, the injury to young corn consists invariably in the eating out of the bud. After the corn has tasselled and the ears have begun to form, the worms feed principally in the tip of the ears and cut off the silks. In this particular, their work is much more serious than that of the roasting ear worms as they may be nearly full-grown when the attack begins. (See Pl. 3, fig. 3). At a still later stage in the growth of the corn the worms bore into the side or base of the ear and feed upon the soft juicy grains. (See Pl. 3, fig. 2). As many as seven specimens have been found in a single ear. At a still later stage in the development of the corn, the worms have been observed boring into the stalk sometimes at the base of the plant and sometimes at the base of the ear. Serious loss was sustained at Benton, Ala., in August, 1912, by corn blowing over because the stalks had been weakened by such attacks. In South Alabama in 1912, the grass worms completely destroyed three successive plantings of corn in many fields.

In most cases the injury to grasses consisted simply in the eating of the leaves but where a large grass as Johnson grass, was attacked, the injury was often in the bud and similar to the attack on young corn. When sugar cane or sorghum were the food plants the method and place of attack was practically the same as with young corn. Young cow peas, beans, etc., may be cut off at the surface of the ground and a small portion of the tender stem, which is a favorite food, may be eaten. After peas, and related plants have grown older, most of the feeding is upon the leaves and leaf stems where the worms are protected from the heat of the sun. The injury to sweet potatoes is similar with perhaps a greater tendency toward the destruction of the leaves rather than of the leaf stems. Where

present in large numbers, however, complete defoliation is followed by destruction of stems and vines.

The injury to cotton is varied, no part of the plant being free from attack. During the early part of the season when the plants are tender, lateral branches are cut off causing shoots to appear which rarely develop bolls. While the tender stems are apparently the favorite portion of the plant, the foliage, squares and bolls are also attacked. The attack on foliage invariably begins on the lower shaded leaves making the control difficult, while the injury to squares and bolls is similar to that inflicted by the cotton boll worm, *Heliothis obsoleta*. Grass worms often eat the bark from cotton plants as the cotton leaf worms do when the foliage is exhausted.

The grass worm, appearing so early in the season of 1912, caused serious losses in the oat and wheat crops by feeding on the heads, by cutting into the stems thereby causing them to break over and also by stripping the leaves. Wherever alfalfa was grown in the State a large amount was devoured by the worms.

Injury to Satsuma oranges, pecans, etc., consisted in defoliation of young trees. Bell pepper plants were defoliated and occasionally the tender flesh of the pod would be destroyed, but the caterpillars seemed to avoid feeding upon the seeds.

THE ARMY HABIT.

The grass worm occurs in less distinctly localized colonies than does the real "army worm" (*Heliophila unipuncta*). This is probably due principally to two factors: first, a lesser tendency among the female moths to deposit eggs in only the ranker spots of growth or on moist areas and, second, a habit of wider dispersion among the newly hatched caterpillars of the grass worm species. The grass worm therefore is less likely to completely exhaust its food supply, but when this does happen, the worms may be forced to adopt the "army" habit in their movement to find fresh fields. The work of the young worms rarely attracts attention from the farmer and even when nearly full-grown, the worms are well concealed during the day if the food is abundant and the sun is shining.

GENERAL DESCRIPTION OF STAGES.

Moth.—The markings of the parent moth of the grass worm are variable, but there are two general classes: first, and most

common in spring, those with forewings and thorax of a dark grayish-brown color with no distinct markings. Second, and most common in fall, those of a light, brownish-gray color with distinct markings consisting mainly of two or three light areas on the fore wings which appear mottled with black, white, reddish-brown and yellowish tints. (See Pl. 1, fig. 9). These noticeable light areas are usually cream colored but may vary in shade, in a number of cases being tinged with reddish brown, yellowish and purple. The hind wings are nearly white with a bluish or purplish tinge which darkens toward the outer margin forming there a dark border which is one of its distinguishing features. The moths vary in length from five-eighths of an inch to seven-eighths of an inch with a wing expanse of from one inch to one and three-eighths inches. When at rest the wings are folded close to the body and when viewed from the side there appears to be a distinct hump on the thorax. In the most distinctly marked forms, these raised thoracic scales are often colored a shiny, metallic brown. While the food determines to a certain extent the color of the larvae and partly explains the variations, it has been proven in the insectary that the variation in the color of the larvae does not produce a similar variation in the color of the adult forms. Often the dullest, least distinctly marked larvae transform into the most ornamental moths. To a certain extent the variation in the color of the adult is seasonal as is indicated by the fact that nearly all moths appearing in May and June were dull gray while the number of brightly marked moths increased through the season so that in September about 97% of the moths emerging were of the ornamental type.

Egg.—The egg is small and nearly spherical but with the base flattened as seen under the microscope. The surface shows a number of vertical ridges converging to the apex of the egg and connected with cross ridges of about the same size giving the egg the appearance of being covered with small rectangular pits. These pits decrease both in area and in depth from the base to the apex of the egg where the surface is almost smooth. The eggs are iridescent and of a light golden-brown color. They are deposited regularly in groups of from 50 to 300, usually in two layers, but sometimes in three or even four layers or decks. As many as 500 have been found in one cluster, the average, however, being between 200 and 300. After the mass of eggs has been deposited on the leaf, the female covers the whole with a mouse-colored layer consisting principally of scales from her own body. (See Pl. 1, fig. 2).

Larva.—When newly hatched, the appearance of the larva differs considerably from that of the full-grown worm. The body is much more hairy and the head is much larger in proportion to the size of the body. The cervical shield is black and the whole body is of a dark shade which rapidly gives way to lighter green as soon as the specimen begins feeding. The larva grows rapidly and in the course of from four to six days attains a length of one-half inch and is then in the third stage at which time lines and markings of the full-grown larva appear. The full-grown larva varies in length from one and one-fourth to one and one-half inches. The body is striped lengthwise on a ground color varying from buff to dull gray or nearly black. (See Pl. 1, figs. 3-4). A narrow, light, usually yellowish stripe runs down the middle of the back. Separating the rather broad, mottled, medium-dark, subdorsal stripe and the still darker broad, lateral stripe is another narrow light stripe. Below the broad lateral, dark stripe appears a light stripe, often wavy and mottled with reddish brown spots. The ventral surface is pale, varying in color from buff to green, and is often mottled with red especially near the light side stripes.

The tubercles appear plainly as very dark areas with the distinct hairs springing from them whether the specimen is dark or light. The cervical shield is dull black while the head is dull brown in color, distinctly mottled and always with the inverted white "Y" clearly defined on the face. During molts the head shield splits along this "Y" mark and this aids especially in the transformation from the larval to the pupal stage.

There is a wide variation in the color and distinctness of the markings of the larva and this fact has led to a great deal of confusion among the farmers observing them. That this variation in color is due in a large degree to the color and character of the food was proven by laboratory experiments. The variation in color of the larva, however, occurs in the same brood and is apparently not connected with the variation in the color of the moths producing them or developing from them. Some of the brightest marked moths have come from the dullest, least distinctly marked larvae.

Pupa.—The pupa resembles that of the regular army worm but is slightly smaller. The color varies from a golden through a mahogany-brown to almost black. When the larval case is first cast, the pupa is light green in color but this shade gives way rapidly to a light brown which grows darker as each day passes. The anal segment ends in a pair of short, sharp, black spines set at a slightly divergent angle to each other. (See

Pl. 2, fig. 6). The spiracles are prominent and a portion of the surrounding integument is of a darker color than the rest of the pupa. The length averages about five-sixths of an inch, varying from one-half to three-fourths of an inch.

As is the case with most other insects, there are four stages in the development of the army worm: egg, larva, pupa and adult. Where the worms come from, the reason for their disappearance from the fields at regular intervals, and other facts which have been generally unknown to farmers, are explained in the following account of the life history of the species.

LIFE HISTORY.

The eggs of the fall army worm are deposited late in the afternoon and in the early part of the night. They are placed by the female moths in clusters of from 60 to 500 on plants which will be suitable as food for the young worms when they have hatched. The eggs may be laid in from two to four layers or decks and the cluster is then covered with a mouse-colored down consisting of a sticky excretion and fine scales from the parent's body. In from two to four days, usually three days, the eggs hatch, some two hours being required for all the larvae to emerge.

The newly hatched larvae make their first meal upon the egg shells, avoiding the downy covering, and then remain close together for two or three hours as if at rest. After this rest and hardening period a wholesale migration takes place, the young worms scattering well before commencing to feed. At this period in their life, the strength and ability of the worms to travel is remarkable. A specimen has been observed by Mr. W. F. Turner to cover a distance of 15½ feet in an hour. Within a short time after the migration begins, the young find a suitable place to feed and their work of destruction is started in the skeletonizing of the leaves. (See Pl. 4, fig. 1). They will remain in this location as long as the food is palatable. Within 24 hours after birth, the larva casts its first skin and then continues its feeding by still skeletonizing the leaves. At this age the worms can travel over a fine sandy soil at the rate of six feet or more an hour and eat many times their weight of food each day. During the first two or three larval stages the worms are hard to reach with arsenical poisons because of this habit of feeding only on the under surface of leaves.

About sixty hours after hatching, the worm casts its second skin and then the markings of the full-grown worm appear

faintly. A change may also take place in the feeding habits during the third stage, some specimens feeding through the whole leaf tissue while others may continue to skeletonize leaves. Specimens in this stage average one-half inch in length and from now on the growth is a little slower. During the next four days the skin is cast twice more and the larva, in the fifth stage of its development, attains a length of from seven-eighths to one inch; the markings of the full-grown worm are distinct and the inverted "Y" on the face is clearly defined.

During the fifth and the sixth, which is the last larval stage, the worms do their greatest damage. They are strong, voracious and somewhat resistant to arsenical poisons. A wide variation in the distinctness of the markings and in the ground color is now apparent. A large series of laboratory experiments proved that the character of the food governs this ground color to a large extent. These two stages, the fifth and sixth, require together about 7 days, after which the worms, usually 1¼ to 1½ inches long, enter the soil near their food plant and form cells in which they change from the larval to the pupal stage. Early in the season while the generations are clearly defined the worms enter the ground for pupation at nearly the same time. Farmers often wonder at this sudden and complete disappearance and think that the worms have gone not to come again. Instead of believing themselves safe from further infestation they should be especially on the lookout for the next generation of worms which will probably become injurious in about 15 to 18 days after the worms of the preceding generation disappeared.

The type of soil has a great deal to do with the depth at which the pupal cell is placed and with the character of the cell. For instance, in a sandy or loose, loamy soil the worms go down about an inch or an inch and a half and spin a loose cocoon, by binding particles of soil together with silk threads. (See Pl. 1, fig. 5). In a stiff clay soil, a cell lying at an angle is hollowed out, rarely deeper than ¾ of an inch, most of the soil being pushed out above the surrounding surface. The formation of the pupal cell and the transformation from larva to pupa requires about 36 hours. The cell itself varies from 6/8 to ⅞ of an inch in length and may be buried from ¼ to 1½ inches beneath the surface of the soil. (See Pl. 1, figs. 7-8). The pupal stage extends over a period averaging nine days but may range between three and sixteen days. In from nine to ten days, there emerges from the pupal cell, the moth or "miller," as it is so commonly called, which is the adult form

of the "grass worm." In the case of the specimens observed in the insectary, the moths have always emerged at night, and this is probably the field habit. The moths, as has been stated, resemble very much some of the cut worm moths. During the day they may be found hiding in thick grass along the edges of neglected ditches and fences or in any dense foliage near the ground. Early in the season the buds of young corn and cane were favorite hiding places for adults. If disturbed during the day, they will fly in an erratic way some ten or fifteen yards and find another hiding place. Late in the afternoon the moths leave their resting places and fly about. By nightfall they are out in full force but are rarely to be seen after ten o'clock. They are strongly attracted to lights and often occur around city arc lights in enormous numbers.

Copulation takes place within from 24 to 36 hours after emergence and within another two days the eggs are deposited. Oviposition usually occurs during the third and fourth nights after emergence. The eggs, averaging between 400 and 500 in number, are placed usually in two or three large clusters, with some scattering smaller groups. The life cycle is then complete and the moth dies, usually within a week after her emergence.

LIFE CYCLE.

The life cycle worked out in the insectary under practically field temperatures and checked by field observations requires, on an average, 30 days. This time is distributed over the different stages as follows: egg stage 3 days; larval stage, 14 days; pupal stage, 10 days; and 3 days for copulation and oviposition by adults. Beginning in April and May, 1912, five distinct generations were traced through the season until October, 1912, each requiring about 30 days. By October the natural enemies had practically exterminated the pest and the final sixth generation occurred in only small numbers in Alabama.

SEASONAL HISTORY.

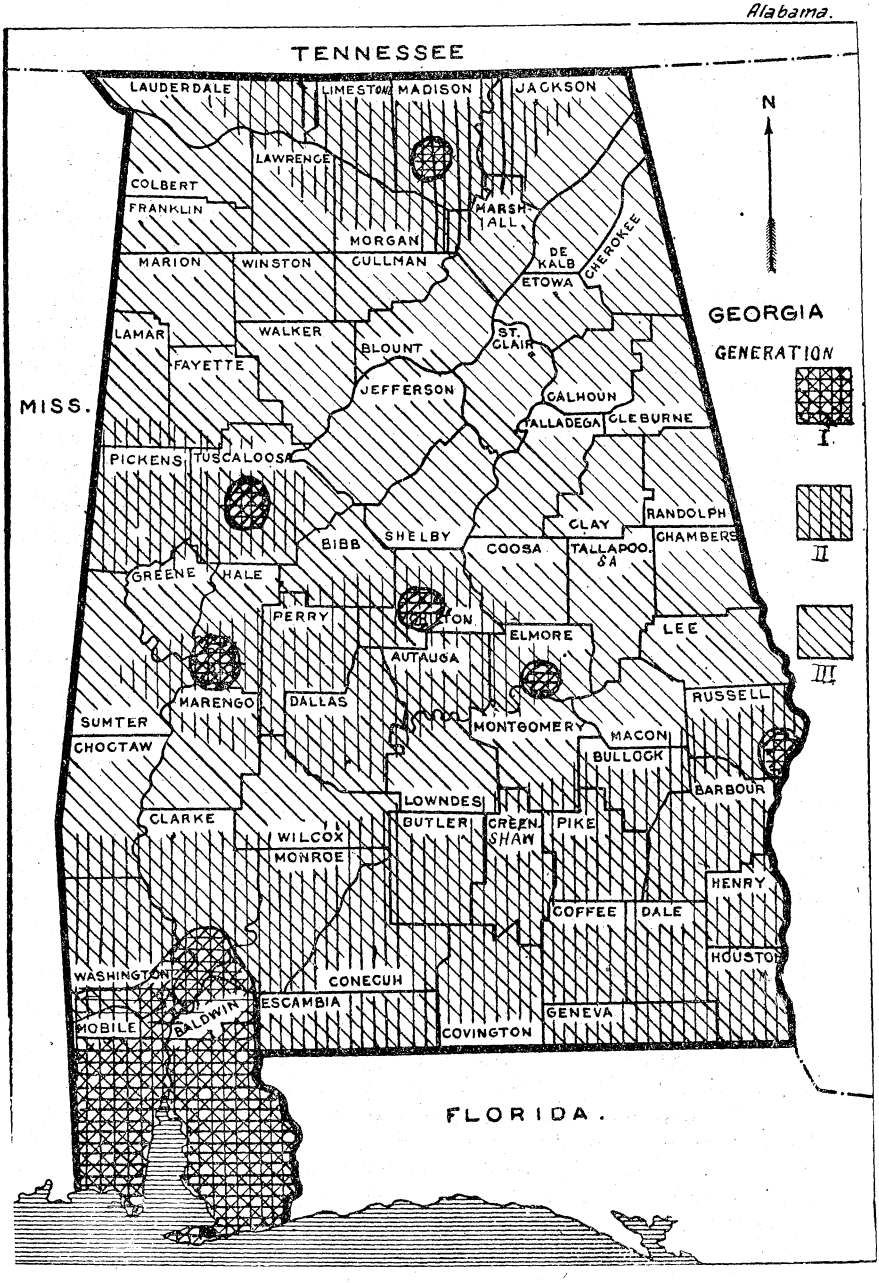
The history of the grass worm outbreak of 1912 can be readily understood by glancing at the accompanying map. The first record of appearance of moths was made by Mr. H. P. Loding of Mobile, on May 4th. These moths were probably the adults of the first spring brood rather than those coming from hibernated pupae. Following close upon this report

(May 15th) came letters by the score from Baldwin and Mobile Counties in regard to large numbers of worms working principally on corn. About the 25th of May the pest was recorded also from Russell, Hale, Greene, Chilton, Elmore, Tuscaloosa and Madison counties, although only a few worms were present and these were working in local areas along river bottoms and on overflowed lands.

Temporary field quarters were established in Mobile and Baldwin counties where life history studies and experiments in control were undertaken. The outbreak during the second generation was still exceedingly local, noticeable damage to crops being confined almost entirely to the low damp places in the fields, leaving the well drained uplands practically untouched. River bottoms and lands which had been overflowed during the winter months were heavily infested. Injury at this time consisted in the complete destruction of young corn and partial destruction of oats, wheat, cotton and sweet potatoes.

Between May 20th and June 1st the transformation of the second generation of larvae to pupae occurred. This period was well marked and the fact that practically all the larvae disappeared from the field at once, as they entered the soil for the change, led many farmers to believe that the pest had gone for good and it was almost impossible to persuade them to take further steps towards its control. During the first week in June large numbers of second generation moths emerged and these spread rapidly over new territory (see map p. 73). The third generation of worms now made its appearance and numerous reports of their presence were received. The worms of this generation did not confine their depredations to the low wet places but spread over the uplands as well where serious damage was done to young corn, cowpeas, sweet potatoes and cotton.

During the latter half of June many of the worms disappeared but the pupation period of this generation was not as distinctly marked as in those occurring before. During the first half of July reports were received from every county in Alabama showing that the moths from the June generation had spread widely. Nearly every common crop was injured, at least to some degree, by this generation. Severe injury to corn was occasioned at this time by the larvae of the fourth generation cutting off the silks of corn ears, preventing fertilization of the grains and also by the feeding of the worms upon the tender grain which had formed. Much rotten corn resulted from this attack of the worms. In some fields cotton was defoliated and squares and bolls destroyed.



GRASS WORM DISTRIBUTION IN ALABAMA, 1912, FOR THREE GENERATIONS.

By the first of August, moths were again abundant and were attracted to city lights by the thousands. About this time two large migrations carried the pest to the middle western, eastern and northeastern states. During the month of August the natural enemies increased rapidly and a partial control was secured in nearly all localities. The worms caused severe damage in local areas in Alabama, however, cowpeas and alfalfa suffering heavily. By this time the generations overlapped considerably, still a distinct September generation, the fifth, could be distinguished. By the middle of September, however, the natural enemies had become so numerous and the migration of moths so general that but little damage was done in Alabama.

During the latter part of September and the early part of October large numbers of moths were found. Apparently these lived several days and most of them died without laying eggs. Moreover, nearly all the egg clusters deposited proved to be sterile, having the typical bluish-green color characteristic of sterile eggs as found in the insectary breeding work earlier in the season. A few of the larvae were found during the month of October both in the southern and central parts of Alabama, but whether these belonged to a distinct generation or were merely belated individuals from the September generation could not be determined positively. Development was certainly less regular and less rapid at this time.

Careful and extensive observations were made during the late fall and winter months showing only one or two moths, one larva, and a large number of pupae. A large number of freshly opened pupal cases was found during December and January showing that predaceous enemies were still at work. From the observations made during the following winter months there can be little doubt that the species hibernates rarely in the adult stage and nearly always in the pupal stage. Most of the successful hibernation probably occurs near the Gulf Coast.

Looking back over the year 1912 we see the beginning of the serious damage with the second generation of worms in May, with a distinct generation each month following until October. The numbers increased up to July but the natural enemies then gained the upper hand and reduced the numbers during August and September. It seems quite possible that the habit of long distance migration in this species may have developed not alone because of the abundant development in infested localities and the consequent exhaustion of food supplies, but also in part at least as a means of escaping by superior power of flight from the presence and influence of the numerous parasitic and predaceous enemies which were thus left behind.

Hibernation of the few larvae remaining took place in October after transformation to the pupal stage. Development at this period was very much retarded.

REMEDIAL MEASURES.

Although the grass worm has caused serious agricultural losses in the South for more than a hundred years, yet little, careful experimental work has been conducted in controlling the pest. During the outbreak in 1912 special attention was paid to this phase of the investigation and many series of experiments were conducted. Four distinct groups of experiments were made in the endeavor to determine the best measures for control: cultural methods, mechanical methods, useless materials and control by use of arsenical poisons. Much time was devoted to testing remedies proposed or recommended by others in order to protect the public from needless waste of money, labor and crops through the use of ineffective or directly injurious materials.

As the subject of control measures is very important to the farmer, they will be discussed separately under group headings.

CULTURAL METHODS FOR CONTROL.

Experiments to determine what effect cultivation might have in grass worm control were begun early in the season at Bay Minette and at other places in Baldwin, Mobile and Washington Counties. The implements used were sweeps and the spike-tooth and disk harrows. Infested fields were cultivated thoroughly with these implements while the worms were present in the soil and active, and again when the pests were in their pupal cells in the soil. Repeated trials showed that even when large numbers of larvae were present in the soil only an occasional one was injured by the cultivation. However, during the later experiments, when the insects were pupating, light shallow cultivation either killed pupae outright or exposed them so that they were killed by the heat of the sun. Careful examination in several places showed percentages of mortality among pupae ranging from 35 to 50 per cent in certain areas in fields where the cultural methods were tested. The disk harrow was apparently more effective than the spike-tooth. The temperature at the surface of the dry soil in the sunshine varied from 120 to 130 degrees Fahr. and this was sufficient to kill the exposed pupae within 30 minutes.

It may often be advisable to plow under deeply all growth remaining in fields where the worms have ruined crops beyond hope of recovery by August. Then disk-harrow the ground thoroughly. Repeat the disking two or three times within ten to twelve days after plowing. This treatment buries many worms deeply, destroys all possible sources of food on the ground, breaks up pupal cells and destroys the insects therein. These three or four workings of the soil in two weeks will insure the starving of young worms, the pupation of the old ones and the destruction of most of the pupae. By the end of the period all surviving the treatment must have transformed and emerged and will have left the field. Any desired cover or fall crop then can be put in with slight danger of reinfestation, and with the soil in unusually fine condition to receive the crop.

MECHANICAL METHODS FOR CONTROL.

Although the worms were present in large numbers, especially during June and July, they rarely assumed the army habit of travelling from one field to another. Only about half a dozen reports of such movement were received in 1912. On two or these occasions mechanical means were used to stop the advance. The first instance was at Theodore in Mobile County, where a furrow was plowed in the path of the advance. As the larvae were crossing, a heavy log was dragged up and down, crushing large numbers. Another experiment was conducted at Grand Bay in July by using a heavy roller where worms were travelling over plowed ground. This was ineffective but when the worms attempted to cross a smooth, hard-packed road, the roller gave excellent results.

USELESS MATERIALS.

The injury done by grass worms to young corn, sugar cane, etc., resembles very cosely the work of *Heliothis obsoleta* which is known by such various common names as bud worm, roasting ear worm, cotton boll worm, etc. Their work in the heart or bud of the young plant led many men to attempt to control the grass worms by sprinkling into the bud such common and inexpensive substances as hot sand, road dust, etc. These treatments were entirely ineffective in controlling the worms although they seemed occasionally to cause them to move. But the movement was only to another location where they continued their feeding and completed their development.

Two cheap materials, Slug Shot and Bug Death, commonly sold on the market as insecticides were quite widely used in the same manner. Although both of these materials have often been proven ineffective and useless with other insects, they were carefully tested against the grass worm. The results showed that they have no value whatever in such work. A brief statement regarding each material should be given as both may still be found on the market and because of the low price at which they are sold they may often mislead buyers who do not know that they are practically worthless. The following quotations are from Dr. J. K. Haywood, Chemist in Charge of U. S. Insecticide Laboratory, Washington, D. C. (b)

Slug Shot.—"There is a compound called 'Slug Shot' that is very extensively sold because of its cheapness. An analysis of this substance shows that it is composed almost exclusively of crude gypsum with a small amount of arsenious acid and copper oxide added, probably in the form of Paris green. The amounts of these two substances in a sample recently examined were only 1.58 per cent arsenious oxide and 0.58 per cent copper oxide. It is needless to say that an article containing as little arsenious oxide and copper as the above will do little or no good as an insecticide, while 5 cents per pound is a large price to pay for a sample consisting of nearly 100 per cent gypsum."

Bug Death.—"This substance is largely composed of zinc oxide with small amounts of iron oxide and lead oxide and about 3.27 per cent of ammonia and potassium chloride. When it is applied to potato vines at the rate of 40 pounds to the acre it has no appreciable effect on bugs (potato bugs) nor does it affect the foliage."

All of the preceding materials lacked killing power.

Gold Dust.—"Another quite widely used material was a solution of Gold Dust applied as a spray or poured into the buds of the young corn plants. The Gold Dust solution seriously injured corn plants upon which it was used. The effect of this spray was peculiar. When applied to the bud of a corn plant containing a worm, the larva immediately came out and lay stiffly on the leaf as though dead. However, as soon as the specimen became dry it became active and returned to its work of destruction. This apparent death of the worms caused great amounts of the Gold Dust solution to be used. Unfortunately the farmers did not wait long enough to see that the worms came back to life but promptly assumed that all still worms

(b) See Farmer's Bulletin No. 146, p. 11.

were dead. Consequently before warning could be given large quantities of this solutions were applied and a few days later the users discovered that the damage to the corn plants from the use of this preparation was very severe. In some quite large fields plants were so rotted by the caustic Gold Dust wash that the stench resulting was nauseating and the loss of the crop was complete.

The experience with these various materials shows plainly the danger of following the advice of uninformed men in such matters of insect control. On the one hand, the treatment may have no effect on either plant or insect, on the other hand, it might be equally fatal to both. In any case, the unfortunate farmer may lose altogether the crop, the cost of the materials and of the labor involved in their application.

CONTROL BY USE OF ARSENICAL POISONS.

Among the many phases of this problem, some of the most important are the following: 1. What are the best arsenicals to use? 2. What are the best forms of materials and methods and times of application with various crops 3. What are the best strengths to apply for efficiency and economy? As may be expected, the answers to these questions may vary widely with different crops.

1. *Arsenical Materials.*—In the work conducted in 1912, it was early determined that Paris green could not be used safely on corn, cowpeas, cane, etc., because of its caustic or burning properties. However, poisoning of grass plots could be done with Paris green as along fence rows, ditches, roadsides, etc. When used for trapping purposes this insecticide gave excellent results.

Both the paste and powdered forms of arsenate of lead were used with excellent results during the course of the investigations. The paste showed no advantage over the powdered form which is recommended as being more stable in form, more easily handled and more cheaply transported, etc. Arsenate of lead is the best material to use in poisoning nearly all crops. Arsenite of zinc was also given several severe tests and from the results it would appear that this insecticide, because of its high arsenic content (see Table 1.) and inexpensiveness, should be more generally used in the control of field crop pests, where arsenical poisons are needed.

In the preparation of poisoned baits, the cheapest form of arsenical is common white arsenic. This material can be obtained through druggists generally. It should never be applied in

sprays or dust form to foliage as it will burn and destroy it far worse than does Paris green or any other standard insecticide.

2. *Strength of Poison to Use.*—Before discussing the results of experiments it may be well to have in mind a comparison of the arsenical content of the various materials mentioned. This comparison is most plainly expressed through the percentages of arsenic or arsenious oxide contained in each, as that is the killing element.

While white arsenic may contain a small amount of impurities it is practically all in the form of arsenic trioxide and may be rated as 100 per cent. or 100 units of arsenious oxide. A comparison of other materials with this shows their comparative killing power.

Table 1. Killing power and cost of various arsenicals.

Group No.	Material	Approx. cost per lb., cents	Arsenious oxide, per cent.	No. lbs. giving 100 units killing power	Cost 100 units arsenous oxide
1	White arsenic	10	100	1	10c
2	Paris green	20	55	2	40c
	Zinc arsenite, D	20	42–45	2¼	45c
	Lead arsenate, D	20	25–33	3–4	60c–80c
	Lead arsenate, P	10	12–15	7–8	70c–80c
3	Slug Shot	5	1	100	5.00
	Bug Death	5	None	——	——

D. indicates dry form used. P. indicates paste form used.

A study of Table No. 1 shows that in cases where there is no danger of injuring foliage, as in the preparation of poisoned baits, white arsenic is much the cheapest material to use. If we disregard cost, we may obtain practically the same killing power through using the number of pounds of each material shown in the fifth column above. The material in group No. 1 should never be used on foliage because it will burn and those in group No. 3 cannot be recommended on account of lack of real value. The materials in group No. 2 may be used on foliage and danger

from burning decreases from Paris green to the arsenates of lead. Arsenite of zinc is the least readily obtainable material, but it is cheap, safe to use and efficient, and should be more widely known.

3. *Forms of Materials and Methods of Application.*—Various strengths of sprays were used ranging from one (1) pound to three (3) pounds of powdered arsenate of lead with fifty (50) gallons of water. While the first one-pound application gave good results in some localities, the three-pound application was not noticeably more efficient than the two-pound. Wherever paste was used, the amount of insecticide was simply doubled. Arsenite of zinc was found to be efficient when used at the rate of one pound to 50 to 80 gallons of water and was not detrimental to the plants when used with an equal amount of lime.

The first experiments conducted consisted in the application of powdered arsenate of lead and arsenite of zinc to the buds of corn plants. This method proved ineffective, however, as the hairy surface of the corn leaves caught and held the particles of dust, preventing them from penetrating to the terminal growing portion or bud of the plant where the worms were feeding.

The next step in the attempt to control the pest in young corn was to make spray applications of arsenate of lead suspended in water. Young corn was treated with the spray, using at the rate of two (2) pound of powdered arsenate of lead and four (4) pounds of the paste form to 50 gallons of water, and the solution was poured into the buds of the young plants. Careful observations of results were made. While this method proved more effective than the dusting of the plants, still it did not give a satisfactory control. After carefully considering these two attempts it was realized that for the spray to be effective, it must be *driven* into the bud of the plant and not simply poured upon it. On small areas it was determined that the arsenate could be most economically and effectively applied to young corn, cane, etc., by means of a knapsack spray pump, being careful to hold the nozzle directly above the center of each plant, thus forcing the spray deep into the buds where the larvae were working.

As a result of numerous field tests it seems that the best control was obtained in nearly all cases through spraying. Dusting experiments on cotton and on other crops having a large leaf area showed that grass worms cannot be as readily controlled by this method as can cotton worms. The difference in effectiveness is due to the very different feeding habits of the

two species. The cotton worms regularly come to the top of the cotton, feeding abundantly upon the tender exposed top leaves upon which the dusted poison naturally settles most heavily. The grass worms start from the ground and work upward, caring less about the tenderness of the foliage than about the protection gained by working concealed in the shaded portions of the plant. They eat last, therefore, those leaves which are most likely to have the dusted poison upon them.

In determining the best methods of control of the pest on sweet potatoes, cowpeas, cotton and other plants having a large leaf surface, both arsenate of lead and arsenite of zinc were used in the powdered form and also as sprays. As a powder neither was effective because of the fact that the top leaves caught and held practically all the poison and prevented its reaching the leaves underneath where the worms were most often feeding. So again the spray was called into use and a field sprayer operated under good pressure gave excellent results. The solution either dripped down or was forced through so as to cover the areas where the larvae were feeding. It was found, however, that these plants were injured more or less when arsenate of lead, without lime, was used stronger than one pound of the powdered form, or two pounds of the paste, to 50 gallons of water. With the addition of freshly slaked lime solution this material may be used safely on any foliage. Zinc arsenite used at the rate of one pound to 80 gallons of water, with a pound of freshly slaked lime added, was also found to be effective and not injurious to the plants treated.

POISONED BRAN MASH.

Before summing up the results secured with arsenates in grass worm control, it will be well to give the results of tests with poisoned bran mash. During the early season when corn was quite small, it was thought that if a pinch of this bait were placed in the bud it would attract and destroy the worms, especially as many of them spent the day in the soil at the base of the plant, coming up to feed at night. The anticipated good results were not obtained in the experiments conducted in the field, one difficulty being that the bait dried and was soon pushed outside the bud altogether, by the rapid growth of the plants.

That a sweetened poison did not have added attractiveness for the pest was proven beyond doubt by laboratory experiments the larvae approaching and feeding on poisoned leaves, sweet

poisoned leaves and untreated leaves of the cotton plant in about equal numbers. In these 1912 bait tests no lemon juice was used as has been found so effective in making bran mash baits for grasshopper control. Later in the season, poisoned bait was used in a peanut field with practically no results and here, if anywhere, the conditions were ideal for control by this method. The peanut plants were upright, 6 to 8 inches high, and did not afford much shade. As a result the worms spent the hot hours of the day in the soil coming up at night to feed. On a half-acre plot a spoonful of bait was placed by each plant late in the afternoon. Counts made before placing the bait revealed an average of 1 1-2 worms to the hill, 90 per cent. of these being in the soil at the bases of the plants. On the day following, counts were again made on the treated and untreated plants, and gave the same average percentage as before, while no dead specimens were found. The field was examined also on the second and third days following the exposure of the bait but no control was secured and by this time the mash had dried completely. Evidently the grass worm, while closely related to the common cutworms, is not as much attracted to poisoned sweets. A few individual farmers, however, reported good results with sweetened baits. It is possible that in some of these cases the disappearance of the worms may have been due to their entering the ground for transformation and not to killing by the baits used.

In 1915, at Auburn further tests were made with poisoned baits for grass worm control. Various combinations of bait versus natural food were tested both in the laboratory and also in the field. The series included baits made with lemon juice, some with oil of lemon, and others without it.

One of the chief difficulties encountered heretofore in the use of baits is that they dry out quickly and when dry lose their attractiveness to insects. To counteract this difficulty and add, if possible, to the effective life of the bait, tests were made to determine the possible value of salt as a component designed to take up and hold moisture. In one series the attractiveness of unsalted bait was compared with that of lots containing respectively 5, 10 and 15 per cent. of salt by weight. In another series the preceding lots without lemon juice were compared with another set containing the lemon juice which has been proven the most attractive component in baits for grasshopper control. Plain wheat bran wet with a molasses solution or with a mixture of ribbon cane and corn syrups, and "molasses horse and mule feed" as it is found on the market

were compared for attractiveness as the base for bait making. The molasses feed used contains ground hay or straw, cracked corn, oats, etc., all moistened thoroughly with a cheap grade of molasses. It would be better not to have the grain present. Possibly a combination of a plain hay and molasses feed with wheat bran would make a still better base for baits, but we have not had opportunity to test this combination.

We shall state merely the most important conclusions based upon this 1915 work and these will be found as numbers 7-16 under the next topic.

In one series of 1915 tests, which confirmed the results of previous less extensive tests, thirty-two lots of bait were used with eighty worms taken from young corn stalks on the day of the tests. Eight glass-covered insect specimen trays 15 by 18 inches were used. Four lots of bait were used in each tray and these were so changed in position that each would have, on the average, the same exposure relative to the direction and intensity of the light.

The following baits were used.

Wheat bran 37.5 grams, 25 grams Alaga syrup, 5 grams salt and 1 gram lemon juice—Bait No. 1.

Same only with 1-2 gram oil of lemon—Bait No. 2.

Molasses feed 50 grams, 12.5 grams Alaga syrup, 5 grams salt and 1 gram lemon juice—Bait No. 3.

Same with 1-2 gram oil of lemon—Bait No. 4.

Tender corn leaves—Bait No. 5.

Tender crab grass—Bait No. 6.

The worms were all started in the middle of the tray and allowed to go to any bait they chose. At hourly intervals examinations were made and the location of all worms recorded. After that they were started in the middle again. In this way four examinations were made between 2 and 5 P. M. and a fifth early the following morning. The summary of these examinations as given below represents very fairly the general results of all of our bait tests.

Table 2. Baits for grass worm.

Box No.	Wheat bran with Alaga syrup and salt		Molasses feed with Alaga Syrup and Salt		Corn Leaves tender	Fresh Crab Grass
	Bait No. 1 Lemon Juiee	Bait No. 2 Oil of Lemon	Bait No. 3 Lemon Juice	Bait No. 4 Oil of Lemon		
1	17	0	11	0	11	10
2	0	3	0	2	12	24
3	0	19	0	2	9	18
4	14	0	7	0	10	14
5	0	2	0	4	23	11
6	9	0	0	0	6	25
7	5	0	12	0	21	10
8	0	5	0	2	11	23
Total	45	29	30	10	104	145
Average per Bait	11.25	7.25	7.5	2.5	13	18.12
Per cent. of worms at each bait	12.4%	8.%	8.3%	3.%	29	40
At bran bait 20%. At molasses feed 11%. At green food 69%						

Total number of observations 362.

SUMMARY OF RESULTS WITH ARSENICALS.

The results of experiments conducted with arsenicals for grass worm control may be summarized as follows, numbers 1-6 being based upon the 1912 experimental work and numbers 7-16 upon the 1915 work:

1. Powdered forms of poisons were not satisfactorily effective at any time when simply dusted upon the various food plants of the pest.

2. Arsenate of lead in spray form was not effective unless applied with force so as to reach the areas where the worms were feeding.

3. Arsenate of lead spray used at the rate of two pounds of powdered or three to four pounds of paste to 50 gallons of water gave a practical control where the worms were feeding in the buds of corn plants, but only when forced deep into the bud beyond the leaf hairs.

4. Arsenate of lead spray used at the rate of one pound of the powdered or two pounds of the paste material, and with an equal weight of lime, in 50 gallons of water gave a practical control on cotton, sweet potatoes, peas, etc., when applied with enough force to reach the areas where the worms were feeding.

5. Arsenite of zinc spray used at the rate of one pound to fifty gallons of water, and with one pound of lime, was effective in its control on young corn where applied with force directly into the heart of the pant. A strength of one pound to 80 gallons of water gave control on the plants having a broad leaf surface. Neither strength was injurious to foliage as applied.

6. Poisoned bran mash made with either Paris green, arsenate or lead or zinc arsenite, but without the addition of lemon or orange juice, was not effective even under conditions where it would apparently be the ideal method of control.

7. The inclusion of salt does not seem to repel worms even when amounting to as much as 15 percent of the weight of the bait.

8. The use of salt does aid in keeping the bait moist and in an attractive condition.

9. The addition of 10 per cent of salt by weight increased by 35 per cent the amount of moisture taken up by the bait during the night.

10. The salted bait was distinctly more moist in the morning, gave off a much stronger odor and was much more attractive to ants and to grass worms than was the unsalted bait exposed beside it on the ground during the night.

11. The addition of lemon juice or oil of lemon did not seem to give any increased attractiveness for grass worms.

12. No form of bait tested seemed capable of attracting grass worms away from crab grass which appears to be their preferred food.

13. Poisoned bait for grass worm control should not include grains on account of the increased danger of killing beneficial wild birds and poultry.

14. The bran bait formula recommended for grass worms is as follows: 100 lbs. wheat bran; 2 lbs. white arsenic; 3-4 gallons cheapest molasses; 10 lbs. salt dissolved in molasses, work into bran thoroughly.

15. Poisoned bait should usually be distributed broadcast, shortly before sunset but may be distributed under exceptional conditions whenever worms are at work.

16. Poisoned bait is not likely to be effective for grass

worms so long as crab grass remains in condition for them to feed upon it. But when the worms are very abundant and are "marching" or moving commonly in daytime, such bait may be very helpful in controlling them.

NATURAL ENEMIES.

Early in the season of 1912, it was seen that unless the natural enemies of the grass worm became abundant, the whole State would be overrun and incalculable loss to all crops sustained, so short was the life cycle and so rapidly did the pest reproduce. Hence a sharp lookout was kept for the appearance of predaceous and parasitic enemies which usually play the major part in controlling such caterpillar pests.

During the month of May, before the worms of the second generation had entered the ground for transformation, those important primary enemies of the caterpillars, parasitic flies, had made their appearance and begun their good work. With the third brood of worms in June, the parasitic flies, increased rapidly. Predaceous insects, including several species of beetles, bugs and wasps and also various birds took notice of the abundant food supply and were feeding extensively on the worms and pupae especially. Hymenopterous parasites were also found to be present in large numbers. The month of July (see map) saw the height of the army worm invasion in all parts of the State. While the numbers of grass worms were large, the parasitic and predaceous enemies also increased very rapidly. Before the worms of the August generation had completed their life cycle it was clearly seen that the natural enemies had the pest under control except in local areas. As a result of this natural control, together with the migration of the August moths to more northern sections, grass worm injury in Alabama was barely noticeable in September. But the good work of the natural enemies did not cease here. Throughout the fall and during the warm days of the winter months, the larvae of predaceous ground beetles were busy and in an examination of a late infested field it was a common thing to find pupal cells which had been only recently entered and the pupae destroyed.

It may be interesting to note that the parasitic and predaceous enemies of the grass worms rendered another valuable service, especially to the cotton farmers, in the season of 1912 in connection with a threatened outbreak of the cotton leaf worm (*Alabama argillacea*). This serious cotton pest had been extremely abundant and injurious through Alabama and many

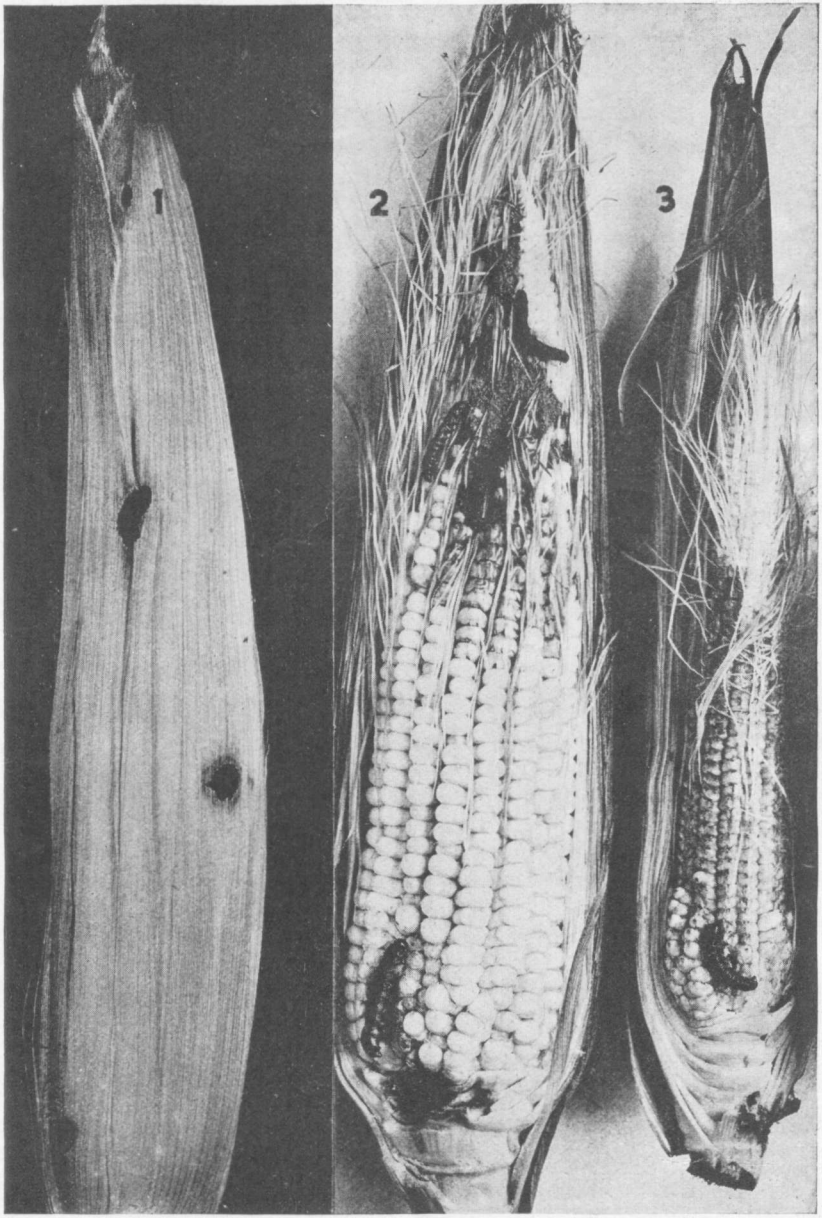


PLATE III. GRASS WORM WORK ON CORN EARS.

Fig. 1, Entrance holes made through the husk; fig. 2, worms feeding on the tender grain after it has reached the milk stage; fig. 3, silks cut so early and completely as to prevent setting of grain. Original.

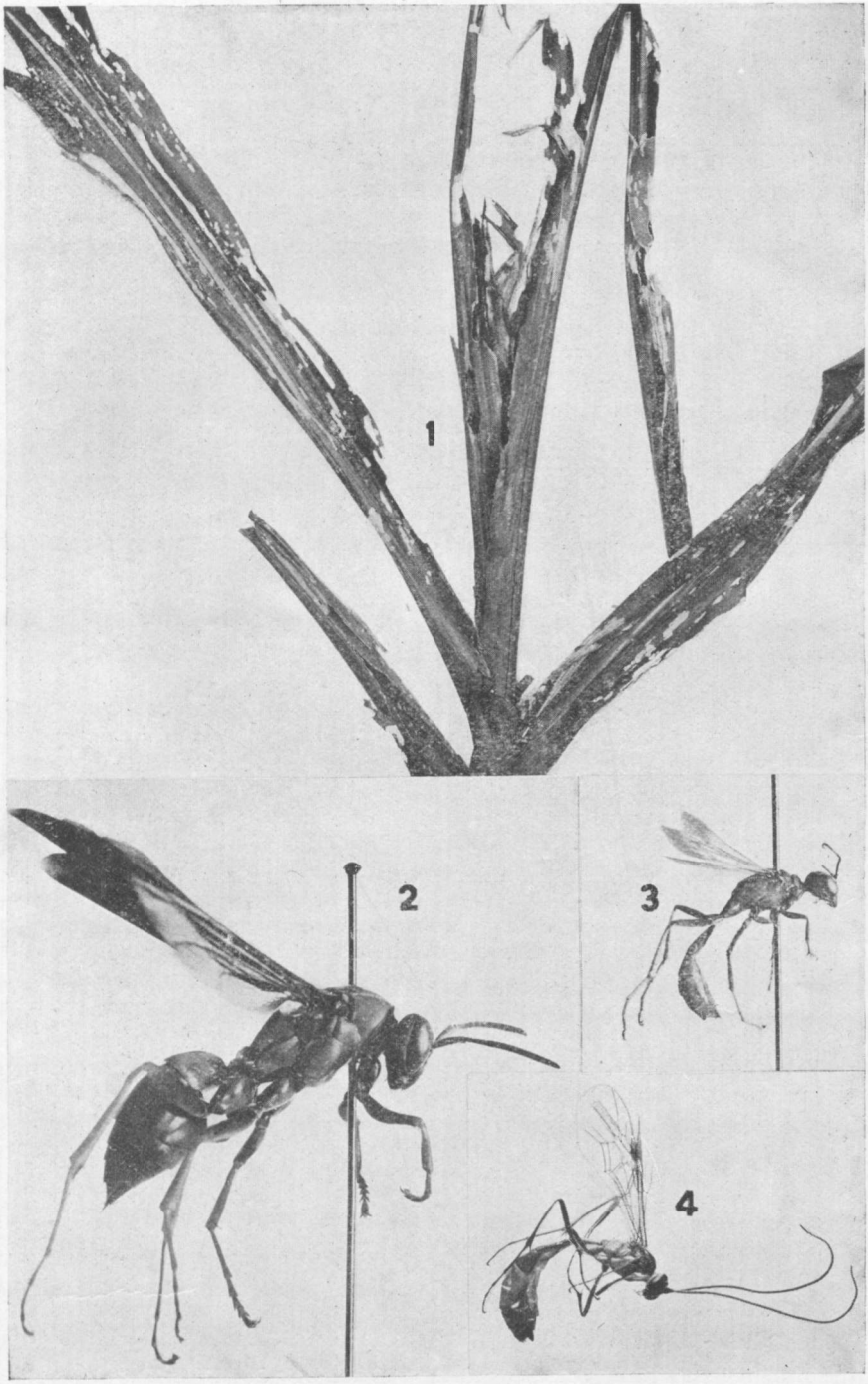


PLATE IV. GRASS WORM WORK ON YOUNG CORN AND SOME GRASS WORM ENEMIES.

Fig. 1, Late corn showing nature of injury (note the skeletonized areas made by young worms); fig. 2, *Polistes bellicosus,* a predaceous social warp; fig. 3, *Pelopaeus cementarius,* a predaceous mud dauber; fig. 4, *Enicospilus purgatus,* a parasitic Ichneumon fly. Figs. 2, 3 and 4 enlarged two diameters. All original.

other states in 1911 and appeared again in July 1912 in such numbers as to cause general alarm. However, the outbreak did not develop as it did in 1911 and the failure of the cotton leaf worm to multiply could apparently be attributed quite largely to the attack made upon this species by some of the natural enemies of caterpillars generally which had been produced in such enormous numbers upon the July generation of the grass worm.

The natural enemies of the fall army worm or grass worm can be grouped under two headings: 1. Predaceous enemies; 2. Parasites. It is hard to say which group is the more important in control, as both were present in large numbers so long as their food supply lasted.

Predaceous Enemies.—Among the predaceous enemies found, the first in importance were some of the large ground beetles and their larvae; second, solitary wasps; third, tiger beetles and their larvae; fourth, birds; fifth, plant bugs; sixth, small tree toads feeding upon adults in corn plants. Altogether it is believed that there were observed 21 species of predaceous insect enemies which seemed to be grouped as follows: Coleoptera, eleven species; Hemiptera, four species; Hymenoptera, six species. Unfortunately not every species seen attacking the grass worm was captured or determined. among the eleven species of beetles which were observed feeding upon grass worms either as adult beetles or in their larval stage, there were representatives of but two families. Six species appeared to belong to the Carabidae or ground beetles and five species to the Cicindellidae or tiger beetles. The two most abundant species were *Calosoma calidum,* a large ground beetle and a brilliantly colored tiger beetle *Tetracha carolina.* Apparently the larvae of this ground beetle did more than any other one predaceous enemy to control the worms. They seemed to have a special ability to locate pupae and in one field in the month of June fully 50 per cent of the army worm pupae were destroyed by this species. Tiger beetles were numerous throughout the State and both larvae and adults were very active in killing and devouring large numbers of the worms.

In fields of cowpeas, sweet potatoes, etc., where there was a heavy infestation with grass worms, large numbers of wasps could be seen flying about, alighting here and there in search of the worms for food. These wasps, including representatives of both solitary and social wasps fed upon and also carried away large numbers of grass worms to their nests where they were stored to become food for their young. The most common species were *Polistes canadensis* a large dark colored social

wasp and *Pelopaeus cementarius* a large slender-waisted solitary wasp. Although not so noticeable as the larger Polistes, the digger wasps were quite abundant and were using the worms as food for their young. In a heavily infested field great numbers of the wasp's egg galleries could be seen in the soil, which, upon examination, showed from 3 to 6 larvae with an egg of the wasp attached.

Two especially active species of the true bugs which attacked the grass worm commonly belonged to the family Ruduviidae, known as assassin bugs. Two species of predaceous Pentatomids or stink bugs were also present and aided considerably in the destruction of worms. These bugs were to be found in the dense growth of plants lying in wait for or stalking some unsuspecting worm which they would kill by inserting their sharp-pointed beaks and sucking the body juices.

Parasites—The number of species of grass worm parasites is smaller than the number of predaceous species but the individuals of some species were much more numerous than in any predaceous species. Reproduction among the parasites was much more rapid than with the predaceous enemies and the number of worms attacked by an individual was greater. Whereas three or four pupae a day would be sufficient food for a well grown larva of a ground beetle, a female Tachina fly or Ichneumon fly might deposit upon unsuspecting worms during the same period of time 40 or 50 eggs. However, much less than half of these might be effective in destroying larvae.

Among the parasites present were representatives of Hymenoptera and of the Diptera. The most abundant and possibly the most destructive enemies, either parasites or predaceous, were the Sarcophagid and Tachinid flies, with the Hymenopterous parasites occupying second place. Several species of these flies were present, the most important of which appeared to be *Sarcophaga georgiana* and *Nemorea leucaniae*.

At least two species of the family of flesh flies (Sarcophagidae) were present in large numbers and both were certainly parasitic. These records add some light as to the parasitic habits of some members of this large family.

The life history of a Tachinid (*Nemorea leucaniae*), determined by breeding several individuals in the field, covered a period of 15 days. The eggs are deposited on the first or second thoracic segment where the worm cannot reach to destroy them. These hatch in 24 to 36 hours and the grub eats its way into the body of the caterpillar where it feeds on the tissues for about five days. The parasite then pupates and remains in this stage

for seven or eight days when the adult emerges, mates and begins the deposition of eggs within the next two days. The parasitic flies were the first enemies observed and their numbers increased so rapidly that during the latter part of July a steady hum could be heard in a heavily infested field.

Among the Hymenopterous parasites, were representatives of the Ichneumon flies, Apantales and Braconidae. Although not so numerous, these parasites were very effective because of the fact that, being inserted as they were directly into the bodies of the worms, few of their eggs were wasted. Probably the most effective individual was *Enicospilus purgatus,* one of the large Icheneumon flies. The life cycle of this species, however, covers about 40 days and naturally they were not as effective throughout the year as the flies which may produce two generations in a month.

Birds—Before leaving the subject of the natural control of the grass worm, it would be well to mention the part played by birds in this work. Observations made throughout the season showed the following birds to be very active in the destruction of grass worms: the common crow, mocking bird, meadow lark, bob white, partridge or quail, various sparrows and, near habitations especially, the English sparrow. Other birds were seen working in infested fields at various times throughout the season, but those mentioned above were present almost continually. Around houses where chickens, turkeys, etc., were kept, good control was maintained over a limited area throughout the year, as the worms were readily eaten by these fowls.

A better general idea of the number and grouping of the natural enemies of grass worms is conveyed by the following partial list which includes only the species which could be positively identified.

PREDACEOUS ENEMIES:

Hymenoptera:	*Polistes bellicosus*
	Polistes canadensis
	Pelopaeus cementarius
	Ammophila sp.
Coleoptera:	*Calosoma calidum*
	Calosoma scrutator
	Tetracha carolina
	Galerita bicolor
	Lebia analis
	Callida punctata

Birds:	English sparrow
	Other sparrows, undetermined.
	Meadow lark
	Quail
	Mocking bird
	Crow
	Chickens
	Ducks
	Turkeys
Amphibians:	Tree toads

PARASITIC ENEMIES:

Hymenoptera:	*Apanteles laphygmae* (?)
	Enicospilus purgatus
Diptera:	*Nemorea leucaniae*
	Sarcophaga georgiana
	Sarcophaga diversipes
	Helicobia halicis

Beside these species many others were observed at work but were either not captured or were not specifically determined.

SUMMARY

The grass worm is an insect of very irregular occurrence in numbers sufficient to attract attention. Outbreaks have usually occurred following overflows or after winters of unusually heavy rainfall. The probable effect of these conditions is to reduce largely the number of the natural enemies which usually hold the species in check.

The species feeds on a large variety of food plants, making use of practically any green vegetation under stress of hunger but evidently preferring grasses and closely related crops such as corn, sugar cane, etc.

The worms are usually distributed quite generally over a field and only rarely assume a distinct "army movement."

In southern Alabama the life cycle required an average period of about 30 days. The various stages averaged as follows: Egg, 3 days; larva, 14 days; pupa, 10 days; adult life to include oviposition, 3 days.

In the early summer the generations were distinctly marked and appeared each month but later in the season there was con-

siderable overlapping of broods. There were six generations in Alabama.

There are six larval stages and most of the damage to crops occurs during the fifth and sixth stages which together cover a period of about a week. When full-grown the worms become 1 1-4 to 1 1-2 inches long.

The moths are strongly attracted to lights and are powerful fliers. The migration instinct seems to develop or increase after the second generation and dispersion to great distances then occurs.

Hibernation appears to occur in Alabama, principally at least, in the pupal stage. No other hibernating stage was found.

Natural enemies, though few in number early in the season, multiply rapidly with succeeding generations.

Only a small percentage (possibly not over 10 to 20 percent) of the eggs of Dipterous parasites produce parasitism among the worms. Most of them are shed with the larval skins before hatching. In Alabama in 1912, parasitic species of Sarcophagiae were more numerous and beneficial than the Tachinidae. Egg parasites were comparatively rare.

Predaceous enemies, consisting principally of adults and larvae of several species of Carabidae and Cincindellidae (ground beetles and tiger beetles) were very effective in controlling the pest in some localities.

In cultural control the most effective practice was found to be light, shallow cultivation during the pupal period. A single harrowing destroyed from 35 to 50 per cent of the pupae. Where the worms destroy field crops in August the best practice would seem to be to plow under the remains of the crop and follow with at least three thorough workings with the disk-harrow during a period of 10 to 15 days, then replant to any fall crop or cover crop desired.

If the worms assume the army movement, they may be effectively checked by several barrier methods including the plowing of one or more deep furrows turning the furrow toward the advancing worms and dragging a log along the furrow to crush the worms therein; strewing air-slaked lime or putting a line of heavy road oil, tar, etc., ahead of the worms; or spraying heavily with an arsenical poison on vegetation ahead of the march, scattering poisoned bran bait, etc., where the hungry worms may get it.

Among the arsenical poisons, the best results were obtained from arsenate of lead and arsenite of zinc, both applied as sprays.

The dusting of arsenical poisons, as commonly practiced for cotton worm control, was not found to be satisfactory for the grass worm on account of the very different feeding habits of the latter species.

In the 1912 work tests made with poisoned bran mash, without the addition of fruit juices, failed to show any valuable results.

More recent tests with poisoned bran mixtures indicate that the common "molasses feed" as sold in the South, is not as good a base for the bait as the wheat bran. To the sweetened bran bait may be added for each 100 lbs. about 2 lbs. of white arsenic, or two lbs. of Paris green, or 2 1-2 lbs. of arsenite of zinc or 4 lbs. of powdered arsenate of lead. The addition of from 5 to 10 lbs. of salt increases the attractiveness of the bait as it will then take up moisture from the ground and the atmosphere and make the bait continue in an attractive condition much longer than it will without the salt. This use of salt in poisoned baits is new so far as we know.