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THE FALL ARMY WORM
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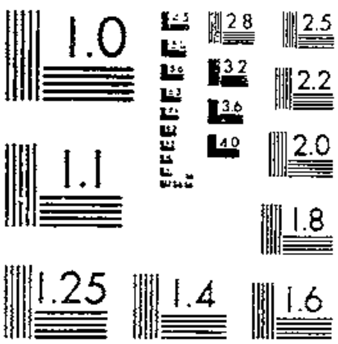

MICROCOPY RESOLUTION TEST CHART
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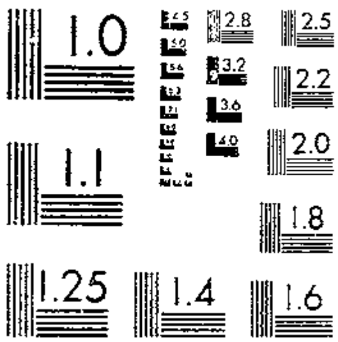

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TECHNICAL BULLETIN No. 34 FEBRUARY, 1928

UNITED STATES DEPARTMENT OF AGRICULTURE
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THE FALL ARMY WORM

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CONTENTS

INTRODUCTION

Among the insect fauna of North America there is, perhaps, no insect of greater interest to the student of economic entomology and to the student of pure biology than the fall army worm (*Laphygma frugiperda* S. and A.). This is one of a few insects known to science that frequently disperse and breed throughout a great part of the United States, only to perish at the end of the summer season. Fall army worms are preserved as permanent residents only in the warmer parts of the South. There are indications that by repeated efforts to inhabit other regions the species eventually may develop a hardy strain that may be able to survive more rigorous climates. The species may then become a permanent resident instead of a migrant.

In a study of this species conducted over a period of years, during some of which serious infestations have occurred, many interesting and valuable data have been accumulated on its biology, its natural enemies, and the means for repressing it.

This bulletin, for convenience, has been divided into three parts. The first part deals with the biology of the insect, especially its habits, and includes technical descriptions of the various stages.

The second part includes various control measures adopted to repress the insect. In the third part the various enemies of this species are discussed.[1]

BIONOMICS OF THE FALL ARMY WORM

HISTORICAL[2]

The importance of the fall army worm as an enemy of grains and grasses was first recognized by Smith and Abbot (*51, p. 191, 192, pl. 96*),[3] who said: "It is worthy the consideration of the husbandman whether, by studying the natural history of this formidable depredator, he could not get the better of it." In this work the writers also give the original description of the insect and illustrate three of its life stages in color, together with one of its favorite food plants, guinea grass (*Sorghum bicolor*).

The insect did not attract much further attention until 1845; however, there is little doubt that during this period (1797–1845) some damage was done to cultivated crops in localized areas, and especially to those growing in the bottom lands of the South. Because of the imperfect means of acquiring information on insect injury at that early period no reliable data have been recorded.

Glover (*23, p. 77–79, pl. 6, fig. 6*), in his Insects Frequenting the Cotton-Plant, mentioning the insect as the "grass caterpillar," states that it did considerable damage to grass, corn, sugar cane, and rice in western Florida in 1845 and to various crops in Georgia in 1854. M. D. Landon, commissioner of agriculture (*36, p. 89–91*), records injury to grass near New Orleans, La., in 1864,[4] while in a monthly report (*56*) a longer account of the same subject is given. Riley (*43*) states that the following year (1868) it ravaged oat, wheat, and grass fields in Missouri. According to Riley (*45*) it again visited Missouri in 1870, extending its ravages into Illinois and Kansas. Various crops were damaged in Missouri, one farmer alone suffering a loss of $1,000. In 1872, in the Report of the Commissioner of Agriculture (*24, p. 118*), the pest was listed as injurious to grass, cowpeas, and corn in Georgia. Thomas (*55, p. 98*), in the Seventh Report of the State Entomologist of Illinois, under the heading of

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[1] Various members of the staff of the Division of Cereal and Forage Insects contributed information on the numerous phases of the problem, and much credit is due them, particularly R. A. Vickery, T. H. Parks, W. R. McConnell, R. N. Wilson, G. G. Ainslie, and R. J. Kewley.

The staff of the Division of Southern Field Crops, through W. D. Hunter and the members stationed in the South, has made valuable contributions to the information on the habits of the insect and in regard to its natural enemies. To W. D. Pierce, formerly of that division, the writer is indebted for use of valuable unpublished notes on the species.

For the drawings accompanying this paper, the writer makes acknowledgment to W. R. Walton and to Miss Esther H. Hart. Thanks are also due W. R. Walton for criticizing the manuscript.

[2] In this section of the bulletin only the major and more important minor outbreaks are discussed.

[3] Reference is made by italic number in parentheses to "Literature cited," p. 88.

[4] "This insect was the source of much amusement on my plantation last year. Reports had come from New Orleans of the destruction of the entire cotton crop by the army worm, and when the grass caterpillar came I took it for the real army worm. Guerrillas, notwithstanding my own fort and the vigilance of Gen. N. B. Buford, commanding the Helena post, had captured my mules and laborers and the crop was quite full of weeds and grass. I many times congratulated myself as I found the insects devouring the grass and weeds, and I thought it was a happy thing to save my crop, and often felt like taking off my hat and thanking the guerrillas for relieving my last forty mules. But I was soon disappointed. I escaped the Scylla but fell upon the Charybdis. No sooner had the grass worm finished its mission and left the rows clean than the legitimate cotton caterpillar (*Noctua xylina*) made its appearance."

"Fall army-worm," states that in about 1868 winter wheat was severely damaged by this insect at one point in Illinois. In 1874 injuries to various crops were reported by Riley (*48, p. 89–98*) from Georgia and Alabama, and Chittenden (*5*) states that in 1878 the insect was reported from Virginia Point, Tex., during December.

In October and November, 1878, various crops were injured in Georgia and South Carolina, according to Riley (*46, 47*).

In August, 1884, from several points in Mississippi it was reported that the larvae were feeding on corn, grass, watermelons, and cotton. In Indiana during September the caterpillars were reported to be feeding on wheat. Forbes (*16*) states that in that year a considerable outbreak occurred on wheat in Illinois. Snow (*54, p. 609–611*) reported injury to wheat in Kansas, and Webster, in unpublished notes in the files of the Bureau of Entomology, reported Laphygma feeding on oats at Oxford, Ind., during the same year. In Illinois the caterpillars ravaged hundreds of acres of wheat.

In 1885 and 1889 Webster (*65, p. 46, 47*) reported that the caterpillars were feeding on corn at Lafayette, Ind.

According to Morgan (*38, p. 735*), injury was done by this pest in 1892 to crops in Louisiana. In 1896 the larvae were reported by Howard (*33, p. 346*) to be again feeding on grass in cotton fields; and that they were unusually destructive to various crops in Florida late in the fall of that year and in the early spring of 1897 was reported by Quaintance (*42*). During 1897 the caterpillars were destructive to violets at Athens, Ga., according to Chittenden (*6*), and simultaneously were reported from points in South Carolina, while in September the insect was reported from Cape Charles, Va.

In 1899 occurred the first general outbreak recorded in the history of economic entomology, when a great portion of the United States east of the Rocky Mountains was invaded by this pest. According to Chittenden (*5*), the larvae were reported as injuring rice at Wilmington, N. C., as early as June 19. Early in July they were reported from another point in North Carolina to be injuring cowpeas, corn, and rice, and were found somewhat later in July on the departmental grounds at Washington, D. C., where they practically destroyed a species of Agrostis (*Agrostis stolonifera*).

During August corn, cowpeas, millet, and vegetable crops were damaged at various points in Illinois, according to Forbes (*17*). Millet and spinach were injured at several points in Maryland. During September forage crops were much damaged at various points in the Southern States (*57; 7, p. 13–45*). In October wheat was severely damaged in eastern Kansas; lawn grass at Buffalo, N. Y.; and corn, sugar beets, cabbage, alfalfa, rye, and clover in Nebraska (*35, p.* [4], *fig.* [*1*]*; 4, p. 47, 48*). Grass and wheat in New Jersey also were injured severely.

Considerable injury was done to crops in Cuba, according to a letter from J. C. Vidal, mayor of Camajuani, who stated that the larvae were so numerous that a full gallon was gathered from a spot 3 square yards in area.

In 1900, according to Felt (*13*), larvae damaged lawns at Buffalo, N. Y. Pettit (*40, p. 30*) reported an outbreak at Chatham, Mich., on the grounds of the experiment station, where corn in the ear, both in the silk and in later stages, was considerably injured.

In 1902, according to Chittenden (*8, p. 113; 9*), the insect was present in considerable numbers in South Carolina, Georgia, and Texas. At one point in Texas 40,000 acres of pasture land were severely damaged. The insect was also reported from South Carolina and Georgia.

Chittenden (*10*) states that in 1904 *Laphygma frugiperda* larvae injured rice plantations along the Cape Fear River in North Carolina; grass and sorghum at Oswego, Kans.; corn on the island of Barbados, West Indies; and tobacco and vegetables in Mexico. In 1905 the insect was abundant at Columbia, S. C. (*58, p. 634*). During this year Fabian Garcia (*21, p. 33*) recorded injuries to alfalfa in the Mesilla Valley, N. Mex., and Smith and Lewis (*53, p. 81*) reported injuries to millet at Statesboro, Ga., during July. In 1906 Howard (*59, p. 510*) recorded that fields of German millet were destroyed in Georgia, kafir and sorghum in Texas, sugar cane in Louisiana, and beets in Wyoming. Smith (*52, p. 102*) reported injury to crops at several points in Georgia.

In 1907, according to Howard (*60, p. 543*), the caterpillars were very destructive to alfalfa in Virginia, Missouri, Texas, and Kansas. In a single county in Missouri a $75,000 loss to the alfalfa crop was reported. Headlee (*28, p. 335*) reported injury to alfalfa at Topeka and Emporia, Kans. Violets were injured at Athens, Ga., rice in North Carolina, and various crops in Mississippi during the same year.

The great general outbreak of the insect in 1912 was unquestionably the most severe that had ever occurred in the United States, notwithstanding the fact that better means of acquiring information on entomological conditions were available than ever before. During this year practically the whole country east of the Rocky Mountains was invaded from Florida and Texas in the South to Maine and Minnesota in the North. The pest was reported from several points in Canada; also from the West Indies, especially from Porto Rico (*32*) and Barbados (*1*). It was also present in destructive numbers in British Guiana (*3*), and was reported from San Salvador, Central America, by P. A. Vitta Corta, of the Instituto Nacional Central del Salvador. The caterpillars appeared in destructive numbers in Florida in April and in southern Alabama the latter part of the same month. In early May moths began to issue from this generation and crossed Alabama and other Gulf States, producing another generation. The moths of the latter generation migrated farther north, repeating the operation again and again. Serious damage was done to forage and other crops in the South; to crabgrass, Bermuda grass, sorghum, peas, alfalfa, and kafir, and to corn wherever grown in that region. Corn was also damaged in many of the North Central States and in Virginia. Wheat was injured in Ohio, Indiana, Illinois, Missouri, Kansas, and especially in Nebraska; oats were injured in Indiana; rye, timothy, and alfalfa in Ohio and Kansas; alfalfa was ravaged in Kansas and to a lesser extent in Indiana, Illinois, Missouri, and Arizona. In the Middle Atlantic States pasture lands and lawns in cities suffered greatly, while corn, alfalfa, and rye were also damaged. Barley was injured in Rhode Island, and lawns suffered injury in some instances in Connecticut. The insect was also abundant at several points in Massachusetts, according to Fernald (*15, p. 87*). In the North Central States, Northeastern States, and in some of the Middle Atlantic States the damage to crops occurred during late summer and early fall. In the Southern States, where the insect appeared much earlier, damage was extended over most of the growing season, especially in the Gulf States. E. O. G. Kelly noticed great swarms of moths at Wellington, Kans., during September of that year. Felt (*14, p. 42*) recorded injury to Hungarian grass and grass lawns in New York City.

In 1915 the insect probably was more abundant than in any year since 1912. It was very common in different parts of South Carolina and other Southern States, and some serious local outbreaks occurred. Sorghum growing among cowpeas at St. Matthews, S. C., was severely damaged, in fact, completely eaten in some fields, while alfalfa was seriously damaged at Fort Motte, S. C., during August. Crabgrass and other forage crops also suffered considerable injury at various places. The insect was also injurious at several points in Georgia, according to Worsham (*67, p. 15*), and according to Hinds (*30, p. 26*), it damaged cowpeas and other crops in Alabama. The insect also appeared in abundance in southeastern Kansas, and was reported from various points in Florida.

In 1918 several reports of injury to alfalfa, corn, and sorghum were received from South Carolina during August. Sherman (*50*) reported injury to peanuts, grass, and corn in eastern North Carolina.

In 1920 occurred what may be considered the most serious outbreak of the insect since 1912. It was much more abundant and did considerably more damage in 1920 than in 1915. At Columbia, S. C., it appeared at the earliest date recorded since 1912. The larvae were taken on young corn in late June and indicated by their stage of development that the migrant moths apparently had arrived about June 20. The species was found in southern South Carolina at the same time, which indicates that the whole State probably was invaded at about the same time. Serious damage was done to various crops in the Southern States. Corn and crabgrass were injured in Mississippi and Georgia; corn, crabgrass, sorghum, peanuts, cotton, and cowpeas in South Carolina; and corn and cotton in North Carolina. In some instances cowpea plants were almost completely defoliated after the grass had been eaten. Sorghum in many instances was completely devoured, and cotton suffered much in many fields. The outbreak apparently was confined principally to the Southern States, as most of the reports of damage came from points in that region.

COMMON NAMES

Laphygma frugiperda is known under a variety of common names throughout the area it invades. The first common name on record given to it by Smith and Abbot (*51*), is "corn-bud-worm-moth." Other names are "fall army worm," "grass caterpillar," "southern army worm," "southern grass worm," "the army worm," "Daggy's corn worm," and "wheat cutworm." On account of its depredations in alfalfa fields in Kansas and Nebraska in 1899, it has been called the "alfalfa worm" by some farmers in that region. In Texas and other Southern States it is often known as the "bud-worm," owing to the fact that the larvae frequently eat out the heart, or bud, of corn and other closely allied plants. Along the Mississippi and other rivers, on lands subject to overflow, this species is called the "overflow worm," from the fact that the larvae frequently do much damage to crops growing on such lands, especially during a year of general invasion. In Florida it is known as the "buck worm" and in Porto Rico as "los gusanos de yerbe." Quite likely it often passes for corn earworm in the United States, and it is so called in Barbados because of a belief that it is the true corn earworm (*Heliothis obsoleta*). This is either because it is often found associated with that caterpillar, feeding on the grains of the ear, or because the injury it does to ears is the same as that done by Heliothis larvae.

In British Guiana the insect is a serious pest of rice, and the larvae are known as "rice caterpillars," while during the outbreak of the insect in Cuba, in 1912, the natives of that country called it "la langosta" (locust).

ORIGIN AND DISTRIBUTION

The fall army worm undoubtedly is tropical in origin, since it does not pass the winter in any of its stages in the United States, except in southern Florida and southern Texas, or in that region of the United States included in the Tropical life zone. According to Hinds and Dew (*31*) it may survive the winter in exceptional years along the Gulf coast. Although there is a possibility of this, it is in reality somewhat doubtful because of reasons given elsewhere in this bulletin.

The species redistributes itself every year, through the migration of the moths, over most of that part of the Austral region included in the Austral life zone, and also over part of that region included in the upper Austral life zone. The insect usually may be taken each year in these regions, and local outbreaks, especially in bottom lands, are not uncommon. During a season of general outbreak, such as occurred in 1899 and again in 1912, the insect not only covers the whole area mentioned but also invades the transitional zone of the Austral region.

Outbreaks, when general and severe, apparently originate in Mexico and the West Indies. During the months from December, 1911, to February, 1912, the species was abundant in Cuba and other tropical countries. The general outbreak which occurred in a large part of the eastern United States during 1912 evidently originated in these countries. During that year (1912) the area invaded in the United States comprised practically all of the States east of the Rocky Mountains, with the exception of North Dakota. (Fig. 1.)

According to a letter received from Arthur Gibson, then chief assistant entomologist of Canada, under date of October 30, 1912, the moths of this species had been taken at the following points in Canada: Ottawa, October, 1901 and 1903; Bridgetown, Nova Scotia, August and September, 1912; Montreal, Quebec, September, 1907 and 1908; Cartwright, September, 1905; and Arvene, Manitoba, September, 1905.

SYSTEMATIC HISTORY AND SYNONYMY

This insect was first described by Smith and Abbot (*51*) in 1797 as *Phalaena frugiperda*. In 1832 Geyer (*22, No. 342*) placed it in the genus Trigonophora but retained the specific name. In 1852 Guenée (*25, p. 157–159*) redescribed the species and assigned it to the genus Laphygma and also described a variant as new under the name *Laphygma macra*. Walker (*63, p. 190–194*) in 1856 described variants of this species under the following three names: *Laphygma inepta*, *Prodenia signifera*, and *Prodenia plagiata*. Glover (*56*) in a general account under the name of *Laphygma macra* (misspelled *machra*), stated that it might prove to be *Phalaena* (*Laphygma*) *frugiperda* S. and A.

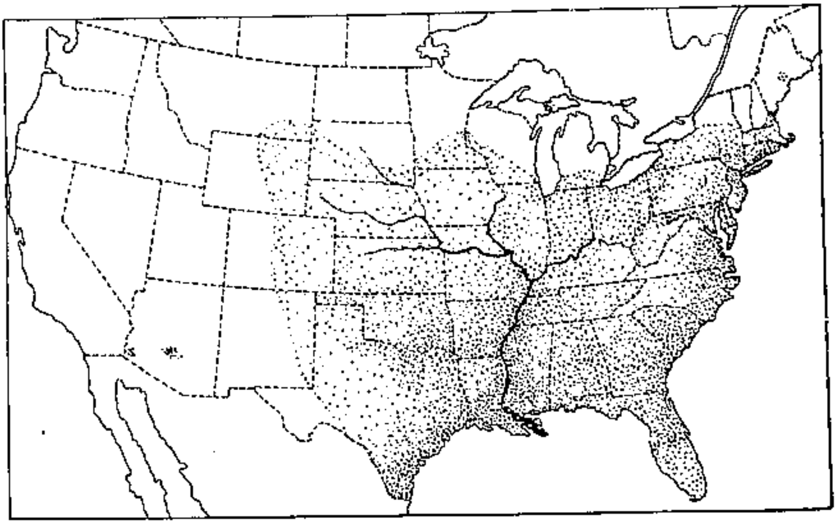

FIG. 1.—Map showing area sometimes invaded by *Laphygma frugiperda*. In the extreme southern portions of this area the fall army worm is constantly present. (Walton and Luginbill)

In 1868 Herrich-Schaeffer (*29, p. 115*), under the caption of *Laphygma frugiperda* Abb., says: "The female is more uniformly colored and less conspicuously ornamented. Undoubtedly Gn. described it [the female] as *L. macra* and Gdl. also considered it under this name."[6] In 1869 Riley (*49, p. 43*) proposed the name of *Prodenia daggyi*, but gave no description. However, during the following year he described the species as *P. autumnalis* (*44, p. 363; 45, p. 109–117*), with original figures of the moth. He observed the marked differences in color pattern among the moths, which are now known to be mostly sexual, and proposed two varieties (giving figures), namely, *fulvosa* and *obscura*. In 1882, in the Report of the Commissioner of Agriculture for 1881–82, Riley (*47*) wrote about the species under the name of *Laphygma frugiperda*, and since that time it has been known, with a few exceptions, by this name.

[6] Translated from the German.

LAPHYGMA FRUGIPERDA (Smith and Abbot)

Phalaena frugiperda Smith and Abbot, 1797 (*51, p. 191*).
Trigonophora frugiperda Geyer, 1832 (*22, p. 22*).
Laphygma macra Guenée, 1852 (*25, p. 157*).
Laphygma frugiperda Guenée, 1852 (*25, p. 159*).
Laphygma inepta Walker, 1856 (*63, p. 190*).
Prodenia signifera Walker, 1856 (*63, p. 193*).
Prodenia plagiata Walker, 1856 (*63, p. 194*).
Prodenia autumnalis Riley, 1870 (*44, p. 363*).
var. *obscura* Riley, 1870 (*44, p. 363*).
var. *fulvosa* Riley, 1870 (*44, p. 363*).

ECONOMIC IMPORTANCE

The fall army worm is a pest of the first order, particularly in the Southern States, as it occurs every year in some part of that region and often does serious damage to crops, especially those of the lowlands. Sometimes this damage is attributed to other insects or other causes. When not exceptionally abundant the larvae may feed like the corn earworms, in the buds of plants, and later, on the grain of the ears, and so may be mistakenly thought to belong to the latter species.

During such general outbreaks as occurred in 1899 and again in 1912 the damage to crops throughout the country was so enormous as to render an estimate difficult, but without doubt it aggregated many millions of dollars. The Southern States during these outbreaks bore the brunt of the loss because a greater number of generations occur in that region, thus extending injury over a much longer period than was the case farther north. However, great damage also occurred in the Middle West, the North, and the East, where uplands as well as lowlands were affected. In 1912 great damage was done to corn, cotton, alfalfa, crabgrass, millet, sorghum, and other field and garden crops. In some instances in the South corn was replanted three or four times, and even the last planting was much injured; in fact, almost destroyed. The alfalfa crop for the season in many cases was almost a total failure. Sorghum planted with cowpeas for hay was in many cases completely eaten, and cowpeas were badly damaged, while older sorghum was stripped, as were corn, kafir, and milo. Young sorghum, eaten down to the ground, had no more than regained some of its former growth when the succeeding generation of larvae devoured it. Rice and millet suffered greatly, as did cotton in some instances. Watermelons and sweet potatoes also were severely damaged.

Considerable injury was done to cotton by the larvae in topping the plants and cutting off squares and branches. In estimating the damage due to topping, members of the late W. D. Hunter's staff made an investigation in infested fields in Louisiana, Mississippi, and Texas and found that 1,491 stalks out of a total of 24,543, or 6 per cent, were topped.

In British Guiana the fall army worm is a serious pest to young rice, attacking the plants when they are at the most critical stage of growth, and if control measures are not immediately taken the larvae destroy the whole crop in a short time.

Van Dine (*61, p. 22*) lists this species as injurious to sugar cane in Porto Rico.

CAUSES CONDUCIVE TO AN OUTBREAK

The probability of a general invasion of the fall army worm in the United States depends to a large extent upon the prevailing weather conditions during the winter months in the region where the insect is a permanent resident. This insect thrives best during periods of cool weather, with an abundance of rainfall. Such conditions are favorable not only for a luxurious growth of grasses and other closely allied plants, but are known to check the multiplication of natural enemies, thus permitting the pest to propagate unhampered in enormous numbers. By the time conditions become favorable for the multiplication of natural enemies the insect has gotten beyond biological control, migrated northward, and invaded the more northerly regions of the United States. If humid weather conditions prevail great damage to various crops may result. During the summer season of 1912 precipitation was heavy in the Southeast and floods were numerous.

During seasons when no general invasion occurs local outbreaks of the insect occur in the South only following a period of heavy rainfall and humid weather.

Bodkin (*3*) sums up the causes influencing the outbreak in British Guiana in 1912 as follows: Insect life was checked early in the year due to a prolonged and severe drought. Later, when rains began, the insect pests became very active, but the parasites, having suffered the greatest setback, were unable to hold the insect in check, and the severe outbreak as described by Bodkin resulted.

FOOD PLANTS

The larvae of Laphygma feed on a large number of plants; in fact, they are almost omnivorous in their food habits, feeding both on field and truck crops, and even attacking the foliage of some forest trees. However, they have a decided preference for plants belonging to the family Poaceae, such as crabgrass, corn, sorghum, and Bermuda grass, and probably would confine their attacks entirely to these plants if they were always available.

Cotton seldom is seriously injured unless it has been poorly cultivated and the field has been overrun with grass; the larvae feeding on the grass, and not finding sufficient supply of this food to reach maturity, go to cotton and do considerable damage to the plants. Cotton fields free from grass seldom, if ever, are invaded, even when they adjoin infested cowpea and grass fields.

The following is a list of food plants upon which the larvae have been found to feed, according to records made by various workers of the Bureau of Entomology and other references upon the subject. Quite likely they feed on many other plants besides those mentioned; however, this list is representative of the various species attacked:

Alfalfa (*Medicago sativa* L.).
Apple (*Pyrus malus* L.).
Asparagus (*Asparagus officinalis* L.).
Barley (*Hordeum vulgare* L.).
Bent grass (*Agrostis stolonifera* L.).
Beet (Beta).
Bermuda grass (*Capriola dactylon* (L.) Kuntze).
Bluegrass (*Poa pratensis* L.) and other species of Poa.
Broom sedge (*Andropogon virginicus* L.).
Buckwheat (*Fagopyrum fagopyrum* Karst.).
Cabbage, common head (*Brassica oleracea* var. *capitata*).

Chick pea (*Cicer arietinum* L.).
Clovers (*Trifolium pratense* L., *T. repens* L., and other species of Trifolium).
Cotton (Gossypium).
Cowpea (*Vigna sinensis* (L.) Endl.).
Cockle bur (*Xanthium commune* Britton).
Corn (*Zea mays* L.), all varieties.
Cucumber (*Cucumis sativus* L.).
Crabgrass (*Syntherisma sanguinalis* (L.) Dulac) and other species of Syntherisma.
Crowfoot grass (*Dactyloctenium aegypticum* (L.) Richt.).
Grape (Vitis), many varieties.
Hollyhock (*Althaea rosea* Cav.).
Johnson grass (*Holcus halepensis* L.).
Lambs quarters (*Chenopodium album* L.).
Millet, cultivated varieties:
  Pearl millet (*Pennisetum glaucum* (L.) R. Br.).
  Hog millet (*Panicum miliaceum* L.).
  Para grass (*Panicum barbinode* Trin.) in British Guiana.
  Texas millet (*Panicum texanum* Buckl.).
  Native species (Panicum).
Morning-glory, wild (Ipomoea).
Nut grass (*Cyperus rotundus* L.).
Oats (*Avena sativa* L.).
Onion (*Allium cepa* L.).
Orange (*Citrus aurantium* L.).
Pea (*Pisum sativum* L.).
Peach (*Prunus persica* Sieb. and Zucc.).
Peanut (*Arachis hypogea* L.).
Pigweed (Amaranthus).
Potato (*Solanum tuberosum* L.).
Purslane (*Portulaca oleracea* L.).
Rhodes grass (*Chloris payana* Kunth.).
Rye (*Secale cereale* L.).
Rice (*Oryza sativa* L. and others).
Rutabaga (*Brassica campestris* L.).
Sorghum (*Holcus sorghum* L.); saccharine group, sorgo, many varieties; nonsaccharine group, kafir, milo, etc.
Spinach (*Spinacia oleracea* L.).
Sugar beet (Beta).
Sandspur grass (*Cenchrus tribuloides* L.).
Scotch kale (*Brassica oleracea* var. *acephala* D. C.).
Sudan grass (*Holcus sorghum sudanensis* (Piper) Hitch.).
Soy beans (*Glycine hispida* Maxium.).
Sugar cane (*Saccharum officinarum* L.).
Strawberry (Fragaria).
Teosinte (*Euchlaena mexicana* Schrad.).
Timothy (*Phleum pratense* L.).
Tobacco (*Nicotiana tabacum* L.).
Tomato (*Lycopersicum esculentum* Mil.).
Tumble grass (*Agrostis hiemalis* (Walt.) B. S. P.).
Turnip (*Brassica rapa* L.).
Violets (Viola), many cultivated varieties.
Watermelon (*Citrulius vulgaris* Schrad.).
Wheat (*Triticum sativum* L.), all varieties.

LIFE HISTORY AND HABITS

THE EGG

WHERE THE EGGS ARE LAID

The eggs of *Laphygma frugiperda* are deposited promiscuously, the female apparently possessing no instinctive habit, peculiar to some insects, of placing the eggs on a food plant of the larva. This indiscriminate placing of eggs may possibly be due to the fact that the larvae are almost omnivorous, and no matter where the eggs are placed there is little chance but that the larvae will find a plant to their liking. The indiscriminate oviposition is especially noticeable during years when outbreaks occur.

During the year of the last general outbreak (1912) egg masses were taken by various members of the bureau staff from a large variety of plants, some of which are cultivated and others growing wild.

Egg masses have been taken from corn, mainly from the underside of the leaves, from wheat, sugar cane, alfalfa, cowpeas, kafir, and tobacco. On the wild plants masses were found on the leaves of crabgrass (*Syntherisma* sp.) and Bermuda grass (*Capriola dac-

tylon). This list includes some of the favorite food plants of the larvae.

Egg masses have also been taken from the foliage of trees such as box elder, catalpa, maple, elm, hackberry, Japan plum, live oak, peach, plum, sycamore, walnut, and date palm. Hubbard (*34 p. 150, 151*) observed the eggs on leaves of the orange. The majority in this list of plants are not food plants, and consequently, when the larvae hatch they must seek elsewhere for food; this they do by spinning threads and dropping to the ground. The honeysuckle (Lonicera), nut grass (Cyperus), geranium, and roses (fig. 2) are other plants upon which egg masses have been placed. Egg masses are often found on sides of houses; in one instance a mass was found on a horseshoe; in another, on a section of rope belonging to a swing; in another case, on a stone walk; and they have been observed on window screens and curtains.

In cages the females deposit the eggs on foliage, on the sides or bottom of the cage, or on the cheesecloth top of it. In a great many cases they prefer to place the eggs on the underside of the cloth top. The probable reason is that the eggs may be more easily attached to the strands of cotton cloth than to the glass side of the cage, or even to the foliage.

PERIOD OF OVIPOSITION

The length of the period of oviposition depends somewhat upon temperature conditions, being shorter in the summer months than during the fall. At Columbia, S. C., this period varies from 4 to 17 days. The majority of the eggs, however, are deposited during the first four or five days after the female begins to oviposit. In cases where egg laying extends over a long period, very few eggs are deposited during the latter part of the period, as the female by that time is nearly spent. At Brownsville, Tex., during August this period extends over only a few days. In the majority of cases two days, and in some cases only one day. Quite likely the higher temperature, by inducing greater activity and shortening the life period of the adult, causes the females to lay their eggs within a shorter period at Brownsville than at Columbia, where the temperatures are lower during that season of the year.

NUMBER OF EGG MASSES AND NUMBER OF EGGS

Considerable variation has been observed in the number of egg masses deposited by one female. It is quite likely that the number of masses per individual in nature is not so great as has been observed in cages. Moths closely confined in cages often disturb each other, and the females busy ovipositing may cease temporarily, continuing subsequently at a different place.

By referring to Table 2 it will be observed that the largest number of egg masses deposited by one female during one day was 8, and the maximum total for one individual was 13. The total number of egg masses for the 6 females in the cages was 43, or an average of 7⅙ for each female.

The number of eggs in one mass in the Brownsville experiment varied from 9 to 349, with an average of approximately 143 eggs. At Columbia, S. C., the number of eggs in a mass as a rule was

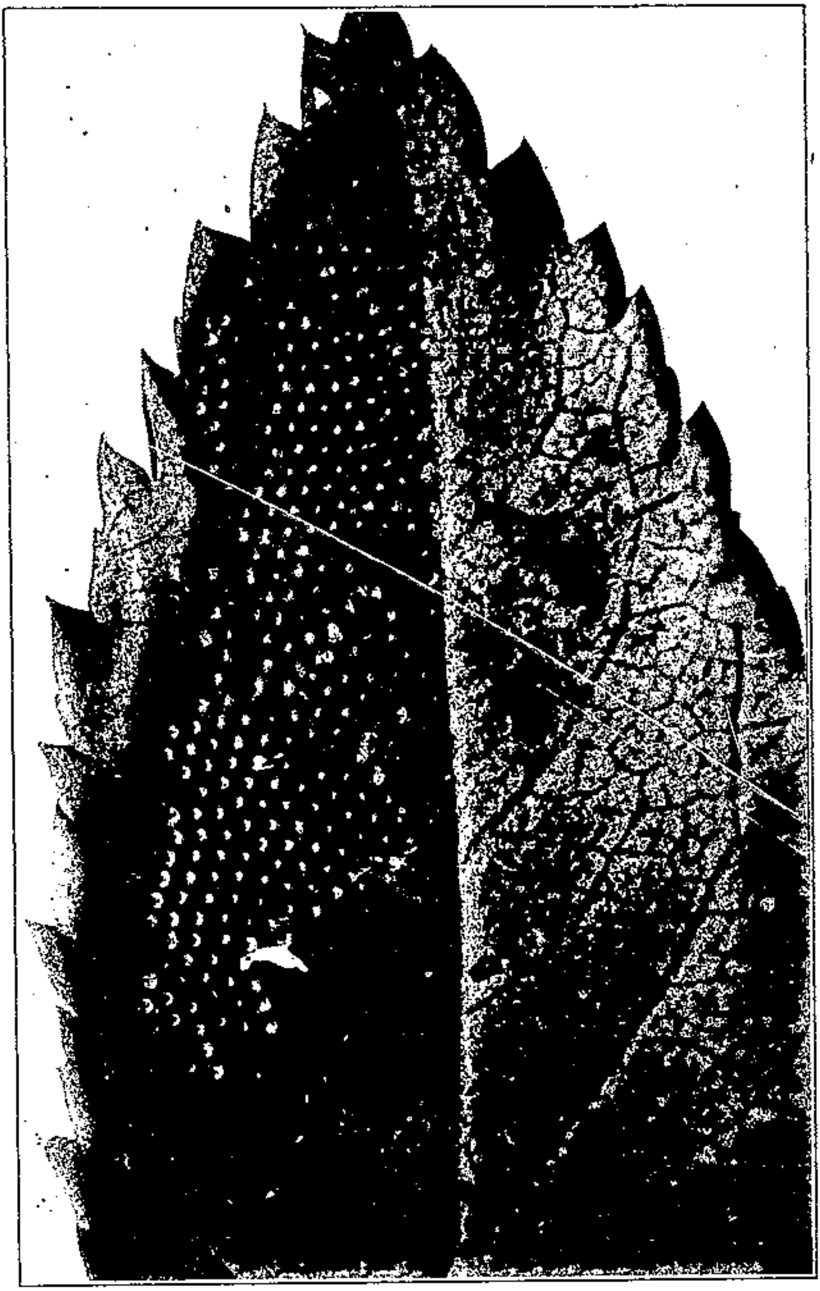

FIG. 2.—Eggs of *Laphygma frugiperda* on the underside of a rose leaf. (Photo by W. D. Pierce)

greater. This may be due to the fact that eggs were deposited in fewer masses. In a lot of 9 egg masses at Columbia, the number of eggs per mass varied from 44 to 593, with an average of 243.

At Columbia, S. C., the number of egg masses deposited by any one individual during her whole life varied from 1 to 13, with an average of 6.7+ in a series of 19 individuals during August, September, and October, 1916.

FERTILITY

Practically all of the eggs from a fertilized female are fertile and hatch. In many cases, however, several larvae in a mass failed to emerge from the eggs, possibly because they had been injured by others that had emerged from the same mass.

MANNER AND RATE OF OVIPOSITION

The moth of *Laphygma frugiperda* deposits her eggs in a mass consisting of two or three layers, or decks, superimposed on each other. The bottom layer contains by far the largest number of eggs, the top layer often containing only a small number. Sometimes, however, the eggs are placed in heaps. This may be because the female was in a cramped position when ovipositing in confinement, as in nature the eggs are always found in layers. The eggs are placed very close together, and usually scales of the moth cover the mass and make it appear as though it were covered with mold. These scales, which are very small and fine, are loosened from the body of the female while she is in the act of ovipositing, and when the individual egg is placed some of these loose scales adhere to it. The scales therefore are attached as each egg is laid, and are not distributed after oviposition is completed. In oviposition the moth moves the tip of her abdomen with a circular motion.

During the first part of the period of oviposition the moth deposits her eggs at the rate of about one every 6½ to 12 seconds, but during the latter part of the egg-laying period this interval may lengthen to two minutes. According to observations made at Columbia, S. C., during September, 1913, one female deposited a mass of 220 eggs between 9 and 9.30 p. m., or at about the rate of one egg every 8 seconds. Another female deposited 227 eggs on September 6, between 7.45 and 8.30 p. m., or at about the rate of one every six and one-half seconds.

WHEN OVIPOSITION OCCURS

Oviposition occurs at night; it has never been observed during the daytime. The approach of twilight stimulates the moths to activity. Oviposition begins shortly after dark and lasts until midnight, but most of the eggs are laid during the early hours of the night. In cages under observation eggs have been deposited after midnight, but possibly in such cases egg laying was delayed by sudden exposure of the moths to bright electric light, thus forcing the extension of the oviposition period.

DAILY AND TOTAL EGG PRODUCTION

The number of eggs deposited by one moth during one day and during her whole life varies greatly; the reason for this is not definitely known. Females fed on solutions of sugar or honey are more productive than those not so supplied; hence it may be assumed that fecundity is affected by the quantities of food ingested. On the other hand, it is quite likely that some moths naturally are more fecund than others. This variability in number of eggs laid is not peculiar to this particular species, but is found in many other species of Lepidoptera; for instance, among the moths of *Heliothis obsoleta*, where the variation is even greater.

In an experiment conducted at Columbia, S. C., during August, 1913, in four cages each containing one female and two males, the daily egg production varied from a minimum of 25 to a maximum of 620 eggs. (Table 1.) The averages for the four females varied from 107 to 389 eggs. It is, of course, understood that calculations are based on days during which eggs were deposited.

A similar experiment was conducted at Brownsville, Tex. (latitude 26° N., elevation 45+ feet), by R. O. Rosewall, during the same month and year as those carried on at Columbia, S. C. (latitude 34° N., elevation 349+ feet). In this case six cages were run, each of which contained a pair of moths; the minimum number of eggs deposited by any one female on one day was 53, and the maximum number was 1,122. The average daily production of the six females was 512 eggs. (Table 2.)

The average number of eggs deposited by a moth during her whole period of oviposition was in excess of 1,000. In the Columbia experiment (Table 1) the minimum number of eggs laid by one individual was 747, the maximum 2,142, and the average 1,393. In the Brownsville experiment the minimum number was 421, maximum number 1,782, and the average 1,024. (Table 2.) The results in these two experiments show that the minimum, maximum, and average total egg production of one female was considerably greater in the Columbia experiment than in the Brownsville experiment.

TABLE 1.—*Number of eggs deposited by females of Laphygma frugiperda (one in each cage) in one day and during life, at Columbia, S. C., 1913*

Date of oviposition:	Number of eggs
Cage A—	
Aug. 24	106
Aug. 25	58
Aug. 26	163
Aug. 27	154
Aug. 28	187
Aug. 29	44
Aug. 30	00
Sept. 1	35
Total	747
Cage B—	
Aug. 29	531
Aug. 30	602
Aug. 31	620
Sept. 1	000
Sept. 2	232
Sept. 3	132
Sept. 4	25
Total	2,142
Cage C—	
Sept. 7	461
Sept. 8	593
Sept. 9	352
Sept. 10	149
Total	1,555
Cage D—	
Sept. 6	358
Sept. 7	358
Sept. 8	000
Sept. 9	000
Sept. 10	44
Sept. 11	181
Sept. 12–17	185
Total	1,126

TABLE 2.—*Number of eggs laid by females of Laphygma frugiperda (one in each cage) at Brownsville, Tex.*[1]

Cage No.	Date	Number of egg masses	Number of eggs in each mass	Number of eggs counted at one observation	Number of eggs for each cage
1	Aug. 23	1	169	169	939
	Aug. 25	4	150, 186, 281, 153	770	
2	do	2	88, 333	421	421
3	Aug. 23	5	9, 119, 349, 49, 134	660	1,782
	Aug. 25	8	139, 135, 119, 217, 109, 124, 175, 104	1,122	
4	do	5	151, 221, 69, 39, 118	598	810
	Aug. 26	1	53	53	
	Aug. 27	1	159	159	
5	Aug. 23	6	65, 49, 123, 133, 90, 223	683	1,315
	Aug. 25	4	191, 139, 178, 124	632	
6	Aug. 23	3	56, 131, 246	433	877
	Aug. 25	3	160, 94, 190	444	
Total		42		6,144	6,144
Average			143	512	1,024

[1] Records obtained by O. S. Rosewall.

TABLE 3.—*Length of incubation period of eggs of Laphygma frugiperda at Columbia, S. C., 1913–1918*

Number of egg masses	Date deposited	Date hatched	Length of egg stage (days)	Number of egg masses	Date deposited	Date hatched	Length of egg stage (days)
1	July 2	July 6	4	1	Sept. 30	Oct. 5	5
1	July 4	July 7	3	2	Oct. 1	do	4
1	July 29	Aug. 1	3	1	do	Oct. 6	5
1	July 30	Aug. 2	3	1	Oct. 2	Oct. 7	5
2	July 31	Aug. 3	3	2	Oct. 3	Oct. 8	5
1	Aug. 1	Aug. 4	3	1	Oct. 4	do	4
2	Aug. 2	Aug. 5	3	1	Oct. 5	Oct. 9	4
1	Aug. 3	Aug. 6	3	1	Oct. 6	do	3
1	Aug. 4	Aug. 7	3	1	Oct. 8	Oct. 12	4
1	Aug. 5	Aug. 8	3	2	Oct. 9	Oct. 15	6
1	Aug. 20	Aug. 23	3	1	Oct. 11	do	4
1	Aug. 21	Aug. 24	3	1	do	Oct. 19	8
2	Aug. 22	Aug. 25	3	2	Oct. 13	do	6
1	Aug. 23	do	2	3	do	Oct. 20	7
1	do	Aug. 26	3	3	Oct. 14	do	6
2	Aug. 24	Aug. 28	4	1	Oct. 15	Oct. 24	9
2	do	Aug. 27	3	1	do	Oct. 23	8
2	Aug. 25	Aug. 28	3	1	Oct. 16	do	7
1	Aug. 26	Aug. 29	3	1	do	Oct. 24	8
1	do	Aug. 30	4	1	Oct. 17	Oct. 26	9
3	Aug. 27	do	3	1	Oct. 19	Oct. 28	9
4	Aug. 28	Sept. 1	4	1	Oct. 23	Oct. 31	8
2	Aug. 29	Sept. 2	4	1	Oct. 24	Nov. 2	9
1	Aug. 30	do	3	3	Oct. 25	do	8
1	Aug. 31	Sept. 3	3	5	Oct. 26	Nov. 4	9
1	Sept. 2	Sept. 5	3	3	Oct. 27	do	8
1	Sept. 26	Sept. 30	4	1	Oct. 28	Nov. 5	8
1	Sept. 27	Oct. 4	7	1	Oct. 29	Nov. 8	10
1	Sept. 28	Oct. 2	4	2	Oct. 31	Nov. 9	9
2	do	Oct. 5	7				
2	Sept. 29	Oct. 4	5	Average for 91 masses			5.28

LENGTH OF INCUBATION PERIOD

The length of the egg stage depends primarily upon prevailing temperature conditions. Humidity apparently plays a very small rôle, as eggs of the same age kept in a dry place hatch in the same length of time as do those kept in a moist place.

In the latitude of Columbia, S. C., according to Table 3, the shortest period of incubation between July 2 and November 9 is two days. This minimum period occurred in August. The longest period of incubation is 10 days and may occur during the latter part of October and the first part of November. This table further shows that during July and August the average length of the egg period is three days, during September, three and one-half days, and during October approximately six days. The general average for this stage for the whole period (July 2 to November 9) was 5.28 days.

At Greenwood, Miss., which is in about the same latitude as Columbia, S. C., W. R. McConnell and J. M. Langston observed that during the months of July and August the egg stage varied from two and one-half to four days.

According to records obtained by R. A. Vickery, at Brownsville, Tex., extending over a period of years, the egg stage varied from 2 to 11 days throughout the year. Table 4 gives data selected from a large number of records and shows the variation in the length of this stage for each month of the year. A short egg period of two days is reported for the months of June, July, August, and September, and the first part of October, or for nearly five months of the year. The longest egg period is 11 days, and is recorded for the latter part of December, while the egg period for early January is a close second, being 10 days. The average length of the egg stage for December is seven days, and for January, nine days.

TABLE 4.—*Length of the incubation period of eggs of Laphygma frugiperda throughout the year at Brownsville, Tex.*

Date eggs were deposited	Date eggs hatched	Length of egg stage (days)	Date eggs were deposited	Date eggs hatched	Length of egg stage (days)
Jan. 2, 1914	Jan. 12, 1914	10	Aug. 8-9, 1913 [1]	Aug. 10-11, 1913 [1]	2
Jan. 11, 1914	Jan. 19, 1914	8	Sept. 12-13, 1913 [1]	Sept. 14-15, 1913 [1]	2
Feb. 2, 1914	Feb. 9, 1914	7	Oct. 5-6, 1913 [1]	Oct. 7-8, 1913 [1]	2
Mar. 14, 1916	Mar. 19, 1916	5	Oct. 17, 1913	Oct. 20, 1913	3
Apr. 4, 1916	Apr. 8, 1916	4	Oct. 24, 1913	Oct. 29, 1913	5
May 2, 1916	May 5, 1916	3	Nov. 5, 1913	Nov. 10, 1913	5
May 26, 1916	May 29, 1916	3	Dec. 2, 1913	Dec. 5, 1913	3
June 25-26, 1913 [1]	June 27-28, 1913 [1]	2	Dec. 20, 1913	Dec. 31, 1913	11
July 12-13, 1913	July 14-15, 1913	2			

[1] At night.

Eggs hatched in two days when the mean temperature was 80° F., and when it fell below 69° F. more than four days were required.

W. D. Pierce, in compiling from records the data as to the length of the incubation stage (made by various men in the Division of Southern Field Crop Insects, stationed in Louisiana and Tennessee), found that the average length of the stage for 22 egg masses was 2.3 days at a mean temperature of 80.5° F. The optimum temperature was 79.5° at which the egg period was two days. At either a higher or lower temperature than this, the average period lengthened, but not at so rapid a rate for the higher temperature as for the lower one. W. H. Larrimer, at Nashville, Tenn., in 1913, reported a period of seven days as the length of the egg stage in a lot of eggs that were laid October 11 and hatched October 18.

During August, 1915, while preparing eggs for histological work at Columbia, S. C., the writer made observations on the length of the incubation period in hours. Table 5 shows the results obtained from this study. It may be noticed that the shortest period for any one of the 10 egg masses was 60.5 hours, the longest was 71.5, with an average of 64.6 hours. Table 5 shows further that some of the masses were deposited after midnight, but that none hatched after midnight.

R. N. Wilson obtained an average of two days for the length of the incubation period for 10 lots of eggs, between May 20 and 26 during 1915, at Gainesville, Fla., and the same average for two lots between June 17 and 20, and for five lots between July 20 and 23 during the same year.

TABLE 5.—*Length of egg stage of Laphygma frugiperda in hours; Columbia, S. C., 1915*

Lot	Day and hour eggs were deposited [1]	Day and hour eggs hatched	Incubation period (hours)
1	Aug. 19, 11.45 p. m.	Aug. 22, 7.30 p. m.	67.75
2	Aug. 24, 2.30 a. m.	Aug. 26, 4 p. m.	61.50
3	Aug. 24, 1 a. m.	Aug. 26, 4 p. m.	63.00
4	Aug. 22, 10.15 p. m.	Aug. 25, 7 p. m.	68.75
5	Aug. 24, 2.30 a. m.	Aug. 26, 4.30 p. m.	62.00
6	Aug. 27, 11 p. m.	Aug. 30, 12 noon	61.00
7	Aug. 19, 11.45 p. m.	Aug. 22, 7.30 p. m.	67.75
8	Aug. 27, 9.45 p. m.	Aug. 30, 12 noon	62.25
9	Aug. 29, 8.30 p. m.	Sept. 1, 9 a. m.	60.50
10	Aug. 22, 11 p. m.	Aug. 25, 10.30 p. m.	71.50
Average			64.60

[1] Refers to the time when moth ceased oviposition.

THE LARVA

GENERAL HABITS

The larvae of *Laphygma frugiperda*, immediately upon hatching from eggs, devour the shells from which they have issued. Nothing remains of the egg mass except the fine scales which covered it. After this first meal the larvae remain almost motionless for a period of from 4 to 10 hours, after which they begin to scatter in all directions in search of food, seeking the tenderest portions of the plants. Some larvae, hatching from eggs placed on tall plants, such as mature corn and sorghum, drop to the ground by spinning silk threads. In their descent they may often be blown some distance by winds. This, therefore, may be a means of dispersion which may partly account for the fact that larvae apparently originating from the same egg cluster are found scattered over a considerable area.

This habit of dropping to the ground may be also a means of escaping from enemies, for whenever young larvae are molested they immediately utilize this means of escape, and it is only with difficulty that they are found. When the larvae are older and larger they continue to drop to the ground when danger threatens but do so precipitately and not by means of silk threads. After falling they usually assume a curled-up position, lying perfectly quiet and remaining in this condition for some time. If molested when in this state, they crawl away quickly and conceal themselves under foliage, or show combat. It is not uncommon to find one larva devouring another of the same species, and they do not hesitate to attack larvae of different species. In fact, during an outbreak, numbers of larvae are apparently killed in this way. Some writers go so far as to claim that as many are killed in this manner as are destroyed by other natural enemies, but this is somewhat doubtful. On account of their cannibalistic habit, it is not possible to rear a large number of larvae in a medium-sized cage, unless plenty of food is provided so that the larvae may conceal themselves well among the foliage.

The larvae are most active in the early morning and in the late evening and are known to feed at night. During the middle of the day, if the sun is shining brightly, they conceal themselves under foliage of host plants, unless they are forced by hunger to seek better forage. In the latter case an invasion may take place during the sunniest and brightest weather.

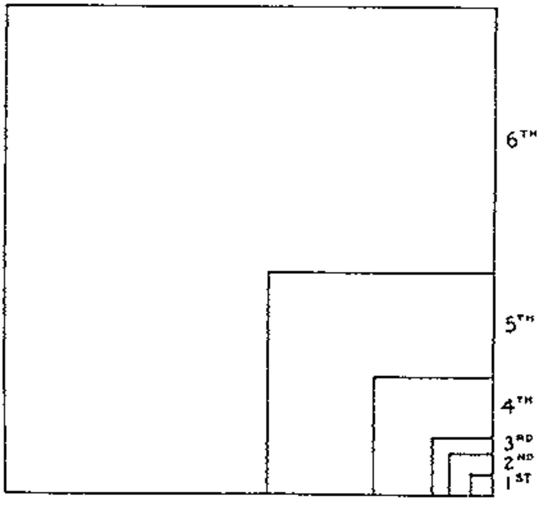

FIG. 3.—Graphic representation of the results obtained in the feeding experiments on *Laphygma frugiperda* given in Table 6, showing the quantity eaten in each instar

The endurance of the newly hatched larvae is remarkable. They have been known to live for more than a day without food, other than the eggshells, being active during most of the time and crawling around in the tube which kept them captive. One larva was observed to crawl 15 feet in one hour before feeding.

AMOUNT OF FOOD CONSUMED BY A SINGLE LARVA

In order to determine the amount of food consumed by one larva during its active feeding period, R. A. Vickery placed two newly hatched larvae in individual vials. Corn leaves were given as food, and measurements were made of the amount eaten daily. At the time of pupation it was found that one larva had eaten a leaf area equal to 90⅕ square centimeters, plus an area of 153 square millimeters, which it skeletonized in its younger stages, while a second larva ate an area of corn leaves equal to 91⅘ square centimeters, plus a skeletonized area of 192 square millimeters.

Samuel Blum made some observations during August, 1921, at Columbia, S. C., on the quantity of food consumed during each larval instar, and also on the total quantity of food eaten during the actual feeding period. A series of six larvae were used for this experiment. They were fed crabgrass. The results of these experiments are summarized in Table 6 and are graphically illustrated in Figure 3. The portions eaten during the first three instars consisted mainly of skeletonized areas.

TABLE 6.—*Quantity of food eaten by one larva of Laphygma frugiperda during each of its instars and total quantity eaten during its entire feeding period*[1]

Number of larva	Area eaten during first instar	Area eaten during second instar	Area eaten during third instar	Area eaten during fourth instar	Area eaten during fifth instar	Area eaten during sixth instar	Total quantity eaten
	Sq. mm.	*Sq. mm.*	*Sq. mm.*	*Sq. mm.*	*Sq. mm.*	*Sq. mm.*	*Sq. mm.*
1	28	82.5	160	680	2,180	11,060	14,700.5
2	16.5	104	206	950	2,940	11,200	15,410.5
3	16.5	82	120	845	2,960	9,060	13,092.5
4	13.5	92	163	530	1,795	12,820	15,413.5
5	25	56	104	450	1,998	8,630	11,263.0
6	25	77	132	412	1,595	10,020	12,861.0
Average	20.75	82.25	140	644.5	2,244.7	10,605	13,806.1

[1] Records obtained by Samuel Blum at Columbia, S. C., August, 1921.

BEHAVIOR

The larvae of *Laphygma frugiperda*, before feeding on foliage of plants, are positively phototropic. After they reach their food plant this tropism is not so conspicuous but is still evident.

When a number of larvae are placed on the bottom of a glass vial that is covered and placed in the sun in a vertical position, the larvae will proceed to the side of the vial nearest the sun and proceed to crawl up that side, almost in a solid phalanx, until they reach the top, where they congregate in a colony nearest the sun. Now if part of the vial at the top is darkened, the larvae will proceed down the side of the vial and congregate along the side nearest the sun on the lower edge of the darkened area. By covering more and more of the vial the larvae may be forced down to the bottom of the vial. However, if the dark shade is removed, they immediately begin to crawl up the side as before. No matter in what position the vial is placed, the larvae always congregate at a point nearest the sun and crawl about in a circle. If the vial is placed in a horizontal position, the long axis of the vial parallel with the equator, at midday, the larvae congregate at a point halfway between the top and bottom of the vial along the upper edge of the side nearest the sun. This intense phototropism may partly account for the fact that young or newly hatched larvae are commonly found on the topmost portions of plants, in the buds.

NATURE OF INJURY TO PLANTS

Young larvae skeletonize the leaves of plants upon which they feed. This habit is peculiar to the first three instars and especially to the first one. A first-instar larva seldom eats entirely through a leaf, but it usually eats the green tissue from one side, leaving the membranous epidermis on the other side intact. The whitish gnawed areas stand out prominently against the dark-green background of the remaining part of the leaf. This appearance is a great aid in determining the presence of the young caterpillars in the crops, as few other lepidopterous larvae in the region invaded by the fall army worm have this skeletonizing habit so well developed. During the second and third instars, although some skeletonizing occurs, the larvae begin to make holes in the leaves and eat from the edges of the leaves inward.

Older larvae, including those of the fourth to the sixth instars, often completely destroy small plants and strip larger ones. Crabgrass is often completely stripped, and even the stems of young and tender plants are eaten to the ground. Young corn from 4 to 10 inches tall is devoured in like manner.

FIG. 4.—Corn plant showing severe injury by the fall army worm. (Walton and Luginbill)

Older corn is completely stripped of the foliage, nothing remaining but the midribs and stalks, while many plants suffer complete loss of the heart or "bud." (Fig. 4.) Corn in the ear has been greatly damaged by the larvae in the Southern States, especially during late fall. (Fig. 5.) In some instances the larvae have been more common on the ears than the earworm (*Heliothis obsoleta*), especially in southern Florida and in Arizona, where the injury inflicted by Laphygma larvae is precisely the same as that caused by Heliothis larvae.

In southern Florida, according to R. N. Wilson, the larvae rarely assume the army worm habit, but feed mainly on the ears of the plants.

FIG. 5.—The fall army worm feeding on corn in the ear

On the Island of Barbados the larvae have been common on the ears, and hence the insect has received the name of "corn worm" on that island.

Alfalfa is devoured to the ground line when young, and when older it is completely defoliated. Sorghum is injured in very much the same way as corn; when young both leaves and stems are eaten, but when older it is stripped of its foliage and eaten out in the bud. Milo and teosinte are damaged in the same way as sorghum. Although the foliage of cowpeas is eaten to some extent by the larvae, the greatest damage to the crop consists of topping the plants. The leaves are cut off, and in many instances whole branches are severed from the parent stalks. Badly infested fields present an appearance of having been hit by a severe hailstorm, the ground being literally covered with leaves. Cotton is injured in a manner very similar to cowpeas, but even less of the foliage is eaten; great injury, however, is sometimes done to the plants by the topping habit, the worm cutting off branches (fig. 6) and almost severing the stalks, sometimes a foot from the top. They also gnaw the bark and bore holes into the squares and stems, like Heliothis larvae.

FIG. 6.—Typical injury to cotton by the fall army worm. (Photo by W. D. Pierce)

The foliage of sweet potatoes, cucumbers, watermelons, and peanuts is eaten and sometimes even the vines are eaten. The foliage of beets, sugar beets, and other crops is also eaten. In fact, the larvae, being very voracious feeders, sometimes appear in immense numbers and devour the tender foliage of a large variety of plants, leaving desolation and destruction in their wake.

DURATION OF INSTARS AND LENGTH OF LARVAL LIFE

The length of each individual instar and the total length of the life of the larva depend primarily upon temperature conditions. During the warmer summer months larvae are very active, feed voraciously, grow rapidly, and consequently have shorter instars and reach maturity sooner than do larvae living in late summer and early fall months, when temperatures are lower and activity, feeding, and growth are retarded.

This fact is shown in Table 7. If the average length of the instars in the two seasons and the average total length of larval life are compared, the following points present themselves: Some of the instars of the larvae living in October are twice as long as those for larvae in July and August. The fourth and fifth instars of the late series are almost twice as long as the corresponding instars in the early series, while the sixth instar in the late series is more than three times as long as the corresponding one in the early series. In the early series the larvae had only six instars, while in the later series a seventh instar occurred (one larva had eight instars but died before pupating). During the fall this additional instar is not uncommon.

TABLE 7.—*Number of instars and length of larval life of Laphygma frugiperda at Columbia, S. C., in 1918*

Instar	Series A, under observation during July and August				Series B, under observation during October			
	Number of individuals	Length of instar (hours)			Number of individuals	Length of instar (hours)		
		Extremes		Average		Extremes		Average
		Minimum	Maximum			Minimum	Maximum	
First	40	45	57	47.9	27	69	95	83.19
Second	40	20	50	34.6	27	47	74	63.88
Third	40	20	50	31.2	27	36	72	52.06
Fourth	40	13	44	32.3	27	48	122	63
Fifth	40	36	75.5	51.1	27	72	131	100
Sixth	40	49	119	93.2	27	115	572	318
Seventh					2	551	575	503

The average length of larval life in series A, based on 40 individuals, was 290.4 hours, and in series B the average length of larval life, based on 27 individuals, was 712.44 hours. The average length of larval life in the late series, therefore, is nearly two and one-half times that in the early series. The minimum number of days required for any larva to reach maturity as given in series A was 261 hours, or about 10.9 days, and the maximum was 321 hours, or about 13.4 days; while in series B the minimum was 489 hours, or about 20.4 days, and the maximum was 1,185 hours, or about 49.4 days. In the last case the larva underwent a seventh instar. This last instar showed no apparent difference in color pattern from that of the sixth instar.

Table 7 also shows that the average length of the second instar is invariably shorter than the length of the first one, the third instar is somewhat shorter than the second, the third instar being the shortest of all; the fourth is shorter than the first, but the fifth is somewhat longer. The sixth instar is of the longest duration, except in the case of seven instars, when the seventh is the longest. The length of the last instar preceding pupation is somewhat increased by the fact that it embraces the prepupal stage. In these laboratory experiments the length of the prepupal stage has been added to the larval life (to its last instar), to which it certainly belongs, but in conducting experiments under normal conditions or in nature it usually is considered as part of the pupal stage, since it occurs in the cell underground.

In the extremes of length of the instars the sixth instar presents the greatest difference, amounting to approximately three days in series A and 19 days in series B.

B. R. Coad, of the Tallulah, La., laboratory, obtained almost the same results for the length of the various instars as did the writer at Columbia, S. C. Mr. Coad gives 1.5 to 2 days for the length of the first instar, as well as of the second and third; 2.5 to 3 days for the fourth, 3 days for the fifth, and 4 to 6 days for the sixth instar, at a mean temperature of 80.8° to 81.8° F.

O. W. Rosewall, at Brownsville, Tex., obtained a length of larval period of 11 days for 30 larvae, 12 days for 154 larvae, 13 days for 30 larvae, in a lot of 219 larvae hatching out July 13, 1913; and an average of 12.8 days for the whole lot for the length of the larval period. In another lot, consisting of 193 larvae, Rosewall obtained an average of 12.3+ days for this period per larva hatching out during June of that same year. These results correspond very closely with those that were obtained by the writer at the same time of the year, at Columbia, S. C. According to C. L. Scott, the larval period during September, at Brownsville, varied from 16 to 21 days, but on an average was about 13 days. At Columbia the average for October is about 30 days.

ACTUAL FEEDING PERIOD OF THE LARVA

The feeding period of the larva is really the entire larval life minus the prepupal stage. This period was determined for the larva of this species by various members of the Bureau of Entomology during 1912. S. E. Crumb, of Clarksville, Tenn., in early August, found that in a lot of 39 larvae the average feeding period was 19 days; the maximum was 24 days, and the minimum 17 days. Coad, at Tallulah, La., obtained an average period of 24.5 days, with a maximum of 27 days and a minimum of 24.2 days, for four larvae during September. Pierce, in a lot of four larvae, at Dallas, Tex., in August, found that this period was 27.7 days, with a maximum of 28 and a minimum of 26 days. At Columbia, S. C., this period was 11 days in a lot of 28 larvae living during late July and early August, 1913, and 12 days for another series of larvae living about the same time. In October this period was observed to be considerably longer, as is shown by Table 7.

The prepupa stage in the summer months may last only one day, but in fall it may extend over a period of from three to five days. During this time the larva does not feed, and, under natural conditions, is usually in its cell underground.

ECDYSIS

When a larva molts the entire integument is not shed, but merely the outer cuticular layer thereof. No outward signs are visible to indicate that the larva is molting until toward the close of the instar, when the process becomes plainly visible.

The larva of this species passes through its final period of ecdysis and casts its skin in a manner similar to that of the larva of *Elasmopalpus lignosellus* Zell., as described by the writer in an earlier bulletin (*37*).

The appearance of a larva in the final act of molting is illustrated in Figure 7, which shows a well-defined colorless area in the region of the neck (*a*). This becomes gradually larger as molting progresses. It is easy to distinguish larvae in this stage of molting, merely by the presence of this patch between the head and the black thoracic shield. During the early period of molting this patch is concealed because the thoracic shield practically always is in contact with the head.

Toward the end of the molting period the larvae are practically helpless and unable to escape or to protect themselves from their enemies.

The duration of the visible period of molting varies from about 12 hours for the first instar to 48 hours for the sixth instar, during the summer months. During the fall, and especially late in the fall, the periods are considerably longer.

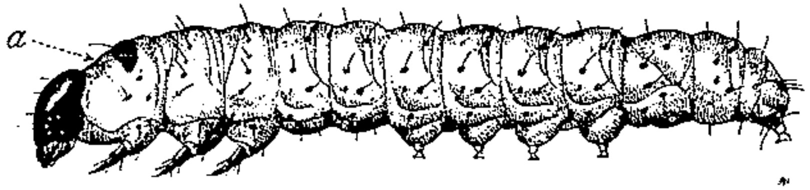

FIG. 7.—A third instar fall army worm in its final molting stage. Note the wide colorless area between the rear of the head and the thoracic shield, marked *a*

Occasionally a larva dies in the final act of molting; sometimes it is unable to free its head from the old mask, and at other times it is unable to withdraw from the old body covering. This may be due to accidental injury while passing through this period.

THE PUPA

WHERE PUPATION TAKES PLACE

Pupation normally occurs in the soil. If the soil is loose, the larva burrows into it to a depth varying from 1 to 3 inches, and constructs a loose cocoon by tying together particles of soil with silk. The cell in which the larva pupates is oval in outline. Where the soil is too firm for the larva to burrow in, it may pupate at the base of a plant by merely bringing dead foliage and sand particles together loosely and making a frail cocoon. Pupae have been found under clods and bowlders in fields where the soil was apparently too firm for the larvae to burrow in. They have also been taken from the tops of corn plants, in the throats of plants, from stalks, from tassels, and especially from the husks of the corn ear. A large number of pupae were taken from the corn husks during a local outbreak at Columbia, S. C., in August, 1920.

LENGTH OF THE PUPAL STAGE

The length of the pupal stage of *Laphygma frugiperda* is greatly influenced by prevailing temperatures. When temperature conditions are right, the moths emerge, irrespective of the season of the year. There are indications that the insect is not able to remain in its pupal stage for a period of two or three months as do many others belonging to the same order. The moths emerge within about 45 days after pupation at the most, even when temperatures are so low that subsequent to emergence they are numb with cold and unable to walk, or else the pupae die. This phenomenon will be discussed more fully elsewhere.

The amount of humidity present does not appear to be a critical factor in influencing the length of the pupal stage. As a general rule, pupae from which adults were desired at the Columbia, S. C., station were kept in glass vials containing a little moistened sand. The vials were stoppered with absorbent cotton, which was moistened as necessary. The humidity in such vials was therefore kept almost at the saturation point. The length of this stage in such specimens was the same as for those kept in soil where the humidity was not nearly as great.

At Columbia, S. C., the pupal stage during the period of July 13 to October 16, according to Table 8, is about 9 days on an average. During the month of July it varies from 6 to 13 days, in August from 7 to 12 days, and during September and October from 16 to 27 days. Larvae in a life-history cage at Columbia, S. C., pupating November 4, 1913, produced moths on December 17 following, after a pupal stage of about 43 days.

TABLE 8.—*Length of pupal stage for Laphygma frugiperda at Columbia, S. C., 1912–1920*

Number of individuals	Dates of pupal periods	Length of pupal stage (days)			Sex		
		Extremes		Average	Female	Male	Undetermined
		Minimum	Maximum				
29	Between July 13 and July 30	6	13	9.1	7	6	16
88	Between Aug. 1 and Aug. 28	7	12	8.8	46	42	
6	Between Sept. 27 and Oct. 16	16	27	18.6	3	2	1
	Average for 123 individuals			9.6			

TABLE 9.—*Length of pupal stage for Laphygma frugiperda at Greenwood, Miss., 1912–1915*

Number of individuals	Dates of pupal periods	Length of pupal stage (days)		
		Extremes		Average
		Minimum	Maximum	
33	Between July 16 and July 31	7	10	8.2
16	Between Aug. 2 and Aug 30	7	10	8.0
28	Between Sept. 1 and Sept. 18	9	11	10.4
3	Between Oct. 2 and Nov. 3	19	23	20.7
	Average for 80 individuals			[illegible]

According to W. R. McConnell and J. M. Langston, the pupal period at Greenwood, Miss, varied from 7 to 23 days between July 16 and November 3. The average for this stage as given in Table 9 is 9.4 days.

G. G. Ainslie, at Orlando, Fla., in 1913, obtained an average of 17.55 days for the pupal stage between February 11 and April 22, a maximum pupal period of 23 days occurring in February and March and a minimum of 13 days occurring during late March and early April. According to Ainslie, the pupal period at Lakeland, Fla., between April 1 and May 3 varies from 11 to 19 days, with an average of 14.14 days.

R. J. Kewley observed at College Park, Md., that the pupal period varied from 8 to 20 days between November 11 and December 8, the average being 15 days.

At Wellington, Kans., E. O. G. Kelly and C. L. Scott obtained as the average a pupal period of 13.8+ days for 15 individuals between August 5 and December 28. The minimum period was found to be 9 days, in September, and the maximum 28 days, in October and November. In a series of seven larvae which pupated October 3 to 5, 1913, at Wellington, Kans., five adults issued October 29, after a pupal period of 24 to 26 days; and 47 larvae collected at Argonia, Kans., on September 13, 1913, and taken to Wellington, entered the soil between September 16 and 18, and moths issued October 6, after a pupal period of from 18 to 20 days.

At Brownsville, Tex., R. A. Vickery and assistants made records of a large number of individuals, extending over a period of years, in order to obtain data as to the pupal period at different times of the year. A summary of these records is given in Table 10. By referring to this it may be observed that the length of the pupal period varies from a minimum of 7 to a maximum of 37 days throughout the year. The average length of the stage for the whole year is 14.23+ days.

TABLE 10.—*Length of pupal stage of Laphygma frugiperda at Brownsville, Tex.*

Date of pupation	Date of emergence	Length of pupal stage (days)	Date of pupation	Date of emergence	Length of pupal stage (days)
Jan. 6, 1914	Feb. 8, 1914	31	July 28, 1913	Aug. 5, 1913	8
Feb. 2, 1914	Feb. 28, 1914	26	Aug. 24, 1911	Sept. 2, 1911	9
Mar. 5, 1911	Mar. 16, 1911	11	Sept. 13, 1910	Sept. 21, 1910	8
Mar. 20, 1911	Apr. 3, 1911	14	Oct. 7, 1910	Oct. 18, 1910	11
Apr. 13, 1911	Apr. 24, 1911	11	Nov. 6, 1913	Nov. 21, 1913	15
Apr. 15, 1911	Apr. 27, 1911	12	Do	Nov. 23, 1913	17
May 1, 1911	May 11, 1911	10	Dec. 6, 1913	Jan. 12, 1914	37
June 6, 1911	June 13, 1911	7			
June 29, 1913	July 6, 1913	7	Average		14.23+
July 6, 1913	July 14, 1913	8			

Coad, at Tallulah, La., observed pupal stages varying from 15 to 31 days between September 19 and November 12, in 1912, in a series of 33 individuals. The average for the entire number was about 17 days. The mean temperature was 72.2° to 72.8° F.

Larrimer, at Nashville, Tenn., recorded a pupal stage of from 19 to 21 days, between September 13 and October 9 in a series of six specimens. The average length of the stage was approximately 20 days.

Vickery, at Brownsville, Tex., observed that one larva pupating January 22, 1913, produced moths February 24–26, 1914, after a pupal stage of 33 to 35 days. The average mean temperature during this period was 61° F.

At Tempe, Ariz., an average of 7.4 days was obtained as the length of the pupal stage in a series of 23 specimens, as given in Table 11. By referring to this table there may be noticed a difference of 2 days between the minimum and maximum number of days of this period during this time of the year.

TABLE 11.—*Length of pupal stage of Laphygma frugiperda at Tempe, Ariz.*

Number of individuals	Date of pupation	Date of emergence	Length of pupal stage (days)
1	July 26	Aug. 2	7
1	do	Aug. 3	8
3	July 27	do	7
6	do	Aug. 4	8
2	July 28	do	7
2	do	Aug. 5	8
1	July 31	Aug. 7	7
1	July 31	Aug. 8	8
2	Aug. 2	do	6
3	do	Aug. 9	7
1	Aug. 3	Aug. 11	8
Average for 23 specimens			7.4

THE ADULT

ACTIVITY OF MOTHS

The moth of this species is not active during the greater part of the day but remains concealed, mainly under the foliage and among refuse. Its dark-gray color renders it inconspicuous, especially when resting near or on the ground. Activity begins a little before sunset, at sunset, or just as the light begins to fade, and reaches its greatest degree a few hours later, provided temperature conditions are suitable. Mating occurs, and eggs are deposited at this time. Hot sultry evenings are conducive to great activity and egg laying, and cool, damp evenings have the opposite effect. During late fall and early winter the nights are often too cool for the moths to show any sign of activity whatever.

FOOD OF THE MOTHS

Moths feed on the nectar of various plants. They have been observed to feed on the nectar of a species of Paspalum grass (*Paspalum boscii* Hitch.) and *Bermuda grass* (*Capriola dactylon* (L.) Kuntze); also on the buds of cowpea plants, selecting these plants from among tall weeds and grass. During the late summer of 1920 moths gathered in swarms on a species of Paspalum grass (*Paspalum dilatatum* Poir.) growing in profusion on the campus of the University of South Carolina, and although they were not feeding when observed, it being early in the evening, there were indications that they would do so later. They were abundant in this grass for a week or more or until it was cut for hay.

The moth is very fond of sweets, and in experiments in which moths have been placed in close proximity to water sweetened with sugar or honey, they immediately extended their proboscides and began to feed.

POLYGAMY

There is evidence of polygamy among moths of Laphygma. In one instance, one male and two females were introduced into a cage and 25 egg masses were taken therefrom. All the eggs were fertile. It is unlikely, however, that polygamy is very common, for as a rule the male is too much exhausted after mating with one female to copulate with another, and frequently he dies within a few days after mating.

OVIPOSITION WITHOUT FERTILIZATION

A virgin female may deposit a few eggs, but such eggs are usually profusely covered with scales which often completely hide them from view. It would seem that greater effort is required to deposit infertile than fertile eggs.

ECLOSION

In eclosion the female sex predominates for the first few days, after which the males appear in greater numbers than the females. This fact is illustrated by the following cage records obtained at Columbia, S. C., in 1913:

Cage I:
- July 27, 24 moths issued, 19 females and 5 males.
- July 28, 29 moths issued, 19 females and 10 males.
- July 29, 20 moths issued, 1 female and 19 males.

Cage II:
- August 25, 5 moths issued, 5 females.
- August 26, 6 moths issued, 6 females.
- August 27, 45 moths issued, 25 females and 20 males.
- August 29, 76 moths issued, 29 females and 47 males.
- August 30, 37 moths issued, 14 females and 23 males.
- September 1–2, 8 moths issued, 7 females and 1 male.
- September 3, 12 moths issued, 4 females and 8 males.
- September 4, 13 moths issued, 13 males.
- September 5, 2 moths issued, 2 females.

Cage III:
- October 10, 16 moths issued, 14 females and 2 males.
- October 12, 32 moths issued, 12 females and 20 males.
- October 13, 4 moths issued, 4 males.
- October 14, 3 moths issued, 3 males.
- October 16, 2 moths issued, 1 female and 1 male.
- October 19, 3 moths issued, 1 female and 2 males.

During the summer emergence of moths takes place only at night, but toward fall and during late fall moths emerge in the daytime as well as at night; in fact, on some days in late fall a greater number emerge during the day than at night. The optimum of emergence lies between 70° and 80° F.

LONGEVITY OF ADULTS

Among the factors that influence the longevity of adults are food and temperature. Moths deprived of food live for a much shorter period than do those that are fed, as shown in Table 12. By referring to this it may be noticed that most of the unfed moths lived from 4 to 6 days and one died in 3 days, while the fed moths lived from 6 to 23 days during the same time of the year. The average longevity of the 10 fed moths recorded in the table is 13.3 days, as compared with 4.4 days for 11 unfed moths.

TABLE 12.—*Difference in length of life of fed and unfed moths of Laphygma frugiperda; also influence of food on oviposition; Columbia, S. C., 1913*

Cage	Number of individuals	Date moth emerged	Date moth died	Length of life (days) Fed	Length of life (days) Unfed	Eggs deposited
A	1 female	Sept. 3	Sept. 26	23		No.
	1 male	do	Sept. 15	12		
B	1 female	do	Sept. 17	14		Yes.
	1 male	do	do	14		
C	2 females	do	do	14		Yes.
	2 males	do	Sept. 11	8		
D	1 female	Sept. 6	Sept. 12	6		No.
	1 male	do	Sept. 26	20		
E	1 female	Sept. 3	Sept. 7		4	No.
	2 males	do	do		4	
F	1 female	do	Sept. 9		6	No.
	2 males	do	Sept. 7		4	
G	1 female	do	do		4	No.
	1 male	do	Sept. 9		6	
H	1 female	Sept. 30	Oct. 6		6	No.
	2 males	do	Oct. 3		3	
	Average for 10 fed moths			13.3		
	Average for 11 unfed moths				4.36	

From numerous tests made it may be assumed that unfed moths seldom, if ever, oviposit, and apparently do not mate. On the other hand, it occasionally happens that females gorge themselves with food and die without ovipositing. From Table 12 it will be observed that no eggs were obtained in cages E, F, G, and H, in which no food was placed, but that eggs were obtained in cages B and C of the same series, in which food was placed.

Moths are longer-lived in late fall than during summer. Perhaps this is due to decreased activity brought about by lower temperatures. According to Table 13, which gives a record of 44 moths living during the period July 26 to November 9, the longevity of the males is 10 days and that of the females 11.4 days. The general average for both sexes is 10.8 days.

This table further shows that the maximum longevity was the same for both sexes, namely, 21 days; the shortest period for a male was three days and for a female seven days. All moths mentioned in this table were adults from life-history cages and were given food consisting of a solution of honey in water or sugar in water.

TABLE 13.—*Longevity of adults of Laphygma frugiperda; records obtained at Columbia, S. C., 1913–1916*

Number of individuals	Date moths issued	Date moths died	Length of life (days)	Sex Female	Sex Male
1	July 26	Aug. 3	8	1	
1	July 27	Aug. 4	8	1	
2	Aug. 19	Aug. 30	11	1	1
1	Aug. 21	do	9	1	
1	Aug. 22	Aug. 25	3		1
1	do	Aug. 30	8	1	
1	do	Aug. 31	9	1	

TABLE 13.—*Longevity of adults of Laphygma frugiperda; records obtained at Columbia, S. C., 1913–1916*—Continued

Number of individuals	Date moths issued	Date moths died	Length of life (days)	Sex	
				Female	Male
2	Aug. 28	Sept. 10	13	2	
2	Sept. 17	Sept. 29	12	1	1
1	Sept. 20	Sept. 25	5		1
1	do	Sept. 29	9		1
1	do	Sept. 30	10		1
1	do	Oct. 6	16		1
1	Sept. 22	Sept. 30	8	1	
6	do	Oct. 5	13	3	3
1	Sept. 23	Oct. 1	8	1	
1	Sept. 24	Sept. 29	5		1
2	do	Sept. 30	6		2
1	do	Oct. 1	7	1	
1	do	Oct. 3	9		1
1	do	Oct. 4	10	1	
2	Sept. 25	Sept. 30	5		2
1	do	Oct. 4	9	1	
1	Sept. 27	Oct. 3	6		1
3	do	Oct. 8	11	1	2
1	do	Oct. 15	18	1	
1	Sept. 28	Oct. 19	21		1
3	Oct. 18	Nov. 4	17	1	2
1	do	Oct. 29	11	1	
1	Oct. 19	Nov. 9	21	1	
Total				22	22
Average length of life for 44 specimens			10.8		

TIME ELAPSING BETWEEN EMERGENCE OF FEMALE AND OVIPOSITION

The following data are given to show the interval between the time of emergence of females from pupae and the time of oviposition. In each case the female, upon issuance, was placed with a freshly emerged male, or in some cases with two males, in a cage of the lantern-chimney type.

The period elapsing between emergence and oviposition is somewhat longer during the fall months than in summer, owing to temperature influence. Moths become inactive as soon as cool nights come and frequently will not even mate. Mating takes place only on moderately warm nights and usually on the second night after the sexes have been placed together, where introduction occurred immediately after their emergence from pupae. The data in Table 14 show the time that elapsed between emergence and oviposition in a few cage experiments conducted at Columbia, S. C., during the summer months.

TABLE 14.—*Time elapsing between emergence and oviposition of Laphygma frugiperda*

Cage No.	Date of emergence	Number of individuals		Date and hour of oviposition	Length of interval (days)
		Female	Male		
1	July 27	1	2	Aug. 1, 12 midnight	5.5
2	do	1	1	July 30, 10.15 p. m.	3.42
3	do	1	1	July 31, 9.20 p. m.	4.39
4	do	1	1	do	4.39
5	do	1	1	July 28, 12 midnight	1.5
6	do	1	1	July 30, 10 p. m.	3.41
7	do	1	1	July 30, 1 a. m.	3.54
8	do	1	1	July 30, 10.30 p. m.	3.43
Average					3.45

DESCRIPTIONS OF LAPHYGMA FRUGIPERDA

THE EGG

(Figs. 8 and 9)

The egg is oblate-spheroidal, circular in cross section, greenish gray when freshly deposited; 12 hours later it is brown, becoming darker, and immediately preceding hatching it appears blackish from the black head of the larva showing through the shell. Polar diameter 0.39 mm., equatorial diameter 0.47 mm. Exochorion sculptured with shallow pits quadrangular to polygonal in outline, those near the equatorial diameter being squarish while those near the poles are trapezoidal, the end nearest the pole being much shorter than the others. Endochorion smooth. The eggs are often covered with down from the moth, and those that are attached to objects are flattened somewhat at points of attachment.

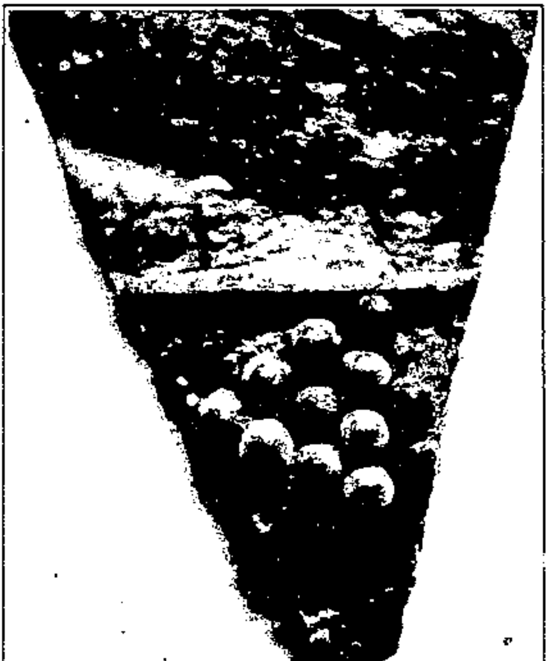

FIG. 8.—Eggs of the fall army worm from which the larvae are nearly ready to emerge. Enlarged × 18. (Photo by W. D. Pierce)

LARVAL INSTARS

First instar (figs. 10, 11, 12, and 13).—Head flattened, circular in outline, jet black, greatest width in line with upper angle of frons, width 0.314 mm.; antennae pale, composed of four joints, first three short and thick, fourth very small; labrum quadrate, supplied with three lateral and three medial setae; mandibles black; frons 0.114 mm. high; longitudinal ridge 0.141 mm. long; adfrontal sutures not visible; incision of dorsal hind margin shallow; frontal setae (F^1) remote from frontal puncture (F^a). Anterior puncture (A^a) between the anterior setae A^1 and A^2. Ocelli 6; IV, V, and VI arranged in the form of a triangle, III mesad of IV, II mesad and slightly caudad of III, I caudad of II, all equal in size: space between III and IV short, IV, V, and VI equally spaced, the distance between two of these being greater than that between any other two.

Cervical shield dusky, rounded behind, almost straight before, length 0.235 mm., width 0.089 mm., bearing four setae on either side of the meson, I^a, I^b, II^a, and II^b, the two former occupying the cephalic margin and the two latter the caudal margin of the shield, the four arranged in the form of a parallelogram; two other setae, I^c and II^c, are situated on a chitinized plate immediately below the shield and slightly separated from it; originally this plate was part of the shield. Anal plate dusky.

Body whitish before feeding and greenish white afterwards, cylindrical, no other color markings; tubercules III and V on thoracic segments 1 and 2 not perceptible; VI absent on all abdominal segments, whereas VII is composed of only one seta on all thoracic segments; otherwise as in later instars. Abdominal segments 3 to 6 bearing prolegs, also segment 10; shields of abdominal prolegs dusky. Spiracles all circular and dusky.

Length of larva 1.68 mm.

Second instar.—Head spherical, circular, amber in color, 0.42 mm. in width; basal parts of antennae pale, distal amber; height of frons 0.20 mm.; length of longitudinal ridge 0.17 mm.; incision of dorsal hind margin 0.07 mm.; adfrontal sutures not visible; frontal setae F^1 migrating toward the lower border of the frons, nearer the frontal punctures F^a than in the preceding stage; cervical shield as wide as the head, 0.16 mm. in length, dusky except where crossed by the dorsal and subdorsal white lines; anal plate dusky.

Body pale whitish with a tinge of brown on the dorsum, the dorsal and subdorsal white lines faintly outlined; tubercles on the dorsum all prominent and black, those on the venter smaller; all the setae now present and perceptible and arranged as given under sixth instar: V very minute on the mesothorax and metathorax. Spiracles all circular.

Length of larva 3.5 mm.

Third instar.—Head spherical, nearly circular in outline, amber colored, free from mottlings; ocular area lighter in dark specimens; height of frons 0.27 mm.; longitudinal ridge 0.31 mm. in length; depth of incision 0.11 mm.; adfrontal sutures faintly visible; adfrontal region paler than the rest of the epicranium; cervical shield dark reddish brown, as wide as head, and 0.41 mm. in length; sharply cut by the dorsal and subdorsal white lines.

Body light brown on the dorsum, greenish on the venter; dorsal and subdorsal white lines plainly visible; secondary white lines appearing immediately above III, wavy and unequal; suprastigmatal band darker than the rest of the dorsum (this band lying between III and the spiracles); III on abdominal segments 4, 5, and 9 surrounded by a dark area; substigmatal band not yet apparent; spiracles on the prothoracic and on the eighth abdominal segments elliptical, all others circular.

Length of larva 6.35 mm.

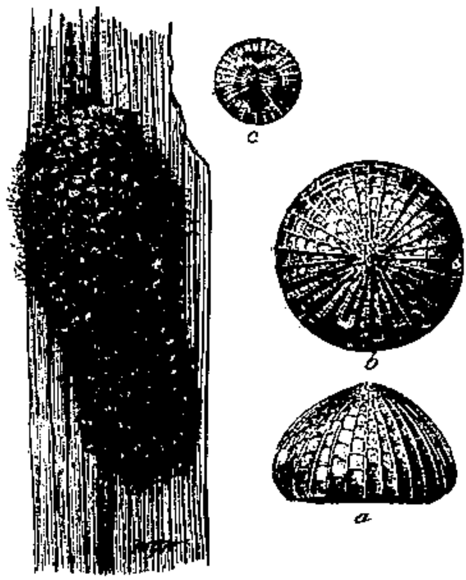

FIG. 9.—Eggs of the fall army worm: Egg mass at left about twice natural size; *a*, highly magnified egg, lateral view; *b*, view from above; *c*, greatly enlarged, the egg nearly ready to hatch, larva visible through shell. (Walton and Luginbill)

Fourth instar.—Head spherical, squarish in outline, reddish brown, mottled with pale patches of white, conspicuous caudad of the ocelli, where they assume the position of lines, well defined; width of head 1.09 mm.; adfrontal sutures now plainly visible, straight, coming to attenuate point on the longitudinal ridge a short distance posterior to the meeting point of the longitudinal ridge and adfrontal ridges; adfrontal ridges converging slightly posterior to point of attachment of tentorial arms to the beginning of the longitudinal ridge; frontal setae F^1 now in line with frontal puncture F^a; height of frons 0.39 mm., length of longitudinal ridge 0.47 mm.; depth of incision of hind margin 0.15 mm.; cervical shield dark brown, as wide as head, and 0.45 mm. in length, the dorsal and subdorsal white lines sharply defined; anal plate dark brown.

Body dark brown on the dorsum, with pale venter and subventer; the subventer mottled with pale brown; dorsal and subdorsal white lines conspicuous; secondary white lines above III obsolete; suprastigmatal band dark brown; substigmatal band whitish, otherwise as before. Spiracles on prothorax and eighth abdominal segments broadly elliptical, all others circular; spiracles with dark-brown borders and pale centers.

Length of larva 10 mm.

Fifth instar.—Head spherical, quadrate, dark brown, except in ocular area and area caudad of this, which is amber, mottled with patches of white on

entire epicranium; width of head 1.00 mm.; adfrontal ridges straight; height of frons 0.56 mm., upper angle obtuse, paler than rest of epicranium and free from white patches; adfrontal pieces whitish as well as a narrow strip on either side of the longitudinal ridge; longitudinal ridge 0.73 mm. in length; depth of incision 0.33 mm.; lower epistoma whitish; labrum whitish; adfrontal sutures plainly visible, undulating, coming to a point as in preceding stage. Cervical shield brown black, 1.26 mm. in width and 0.52 mm. in length, with the dorsal and subdorsal white lines sharply defined.

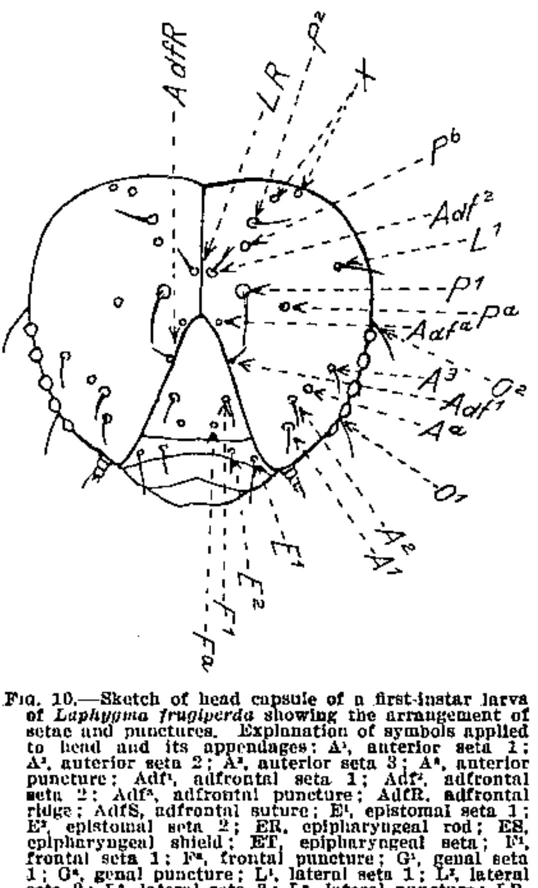

FIG. 10.—Sketch of head capsule of a first-instar larva of *Laphygma frugiperda* showing the arrangement of setae and punctures. Explanation of symbols applied to head and its appendages: A^1, anterior seta 1; A^2, anterior seta 2; A^3, anterior seta 3; A^a, anterior puncture; Adf^1, adfrontal seta 1; Adf^2, adfrontal seta 2; Adf^a, adfrontal puncture; AdfR, adfrontal ridge; AdfS, adfrontal suture; E^1, epistomal seta 1; E^2, epistomal seta 2; ER, epipharyngeal rod; ES, epipharyngeal shield; ET, epipharyngeal seta; F^1, frontal seta 1; F^a, frontal puncture; G^1, genal seta 1; G^a, genal puncture; L^1, lateral seta 1; L^2, lateral seta 2; L^3, lateral seta 3; L^a, lateral puncture; LR, longitudinal ridge; M^1, median seta 1; M^2, median seta 2; M^3, median seta 3; M^a, median puncture; O^1, ocellar seta 1; O^2, ocellar seta 2; O^3, ocellar seta 3; P^1, posterior seta 1; P^2, posterior seta 2; P^a, posterior puncture; P^b, posterior puncture; SO^1, subocellar seta 1; SO^2, subocellar seta 2; SO^3, subocellar seta 3; SO^a, subocellar puncture; X, ultra-posterior punctures; I, ocellus 1; II, ocellus 2; III, ocellus 3; IV, ocellus 4; V, ocellus 5; VI, ocellus 6

Body grayish brown on the dorsum, venter and subventer greenish, the latter mottled with pink; suprastigmatal band dark brown, almost black; substigmatal band pale whitish, filled in with pale reddish-brown mottlings; thoracic legs black; abdominal prolegs with black shields; cephalad of the spiracle of the eighth abdominal segment there is a black spot and another cephalad of III on the first abdominal segment. Spiracles all elliptical, colored as in preceding instar.

Length of larva 17.2 mm.

Sixth instar (fig. 14).—Head (fig. 15) rounded, slightly bilobed, quadrate, reddish brown mottled with patches of white as before, width 2.78 mm., as high as wide, greatest width in line with upper angle of frons. Adfrontal sutures plainly visible, undulating, coming to a point as in previous instar. Adfrontal ridges straight, upper angle obtuse. Frons reddish brown, free from mottlings, 1 mm. high. Incision of dorsal hind margin 0.79 mm. deep. Length of longitudinal ridge 1.19 mm. Antennae (fig. 16), first joint cone-shaped, whitish, long; second joint cylindrical, amber, short; third joint cylindrical, twice as long as the second, amber; fourth joint cylindrical, very small; setae long; papillae conspicuous. Epistoma same color as the frons, postlabrum whitish, wrinkled. Labrum (fig. 17, A and B) pale amber, with a deep median incision somewhat rounded at its base, shallow indentation posterior to base of incision, and another on either side of this in region of median group of setae; lateral setae (L^1, L^2, L^3) along lateral margin, L^2 being long and very close to L^1, which is moderately long; L^3 moderately long and remote from others; of the median group of setae (M^1, M^2, M^3) M^1 is near the base of the incision, M^2 *is antero-laterad of* M^1, M^3 is remote from others and near anterior margin; M^1 is short, M^2 and M^3 are moderately long. Epipharyngeal shield (*ES*) consists of a broad chitinization of the median incision; epipharyngeal setae (*ET*) arranged triangularly near the anterior margin of the shield; epipharyngeal rods (*ER*) conspicuous. Mandibles (fig. 18) black, with two setae on the upper face, near the lower edge, two of the teeth pointed, others blunt. Labium and maxillae as figured (fig. 19), the chitinized areas pale to dark brown, lateral lobes of stipes maxillaris bearing three spines, two close together in the central portion and one in the anterior region; submentum bearing two spines of equal length.

Cervical shield brown black, not quite as wide as head; the dorsal and subdorsal white lines sharply defined.

Body cylindrical, grayish brown on the dorsum, greenish on the venter and subventer, the latter being mottled with reddish brown. Dorsal and subdorsal white lines conspicuous. Suprastigmatal band brown black, especially the upper half, the lower somewhat lighter. Substigmatal band pale, filled in with reddish-brown mottlings. Body widest in region of seventh, eighth, and ninth abdominal segments.

Length of larva 34.15 mm.

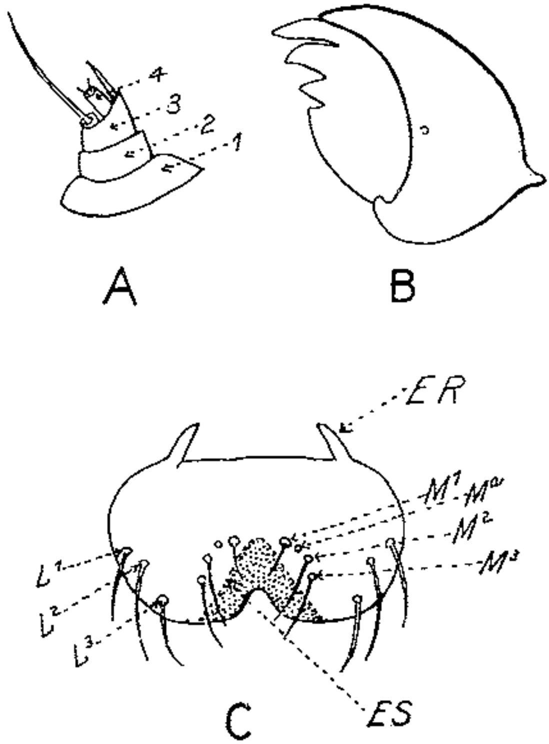

FIG. 11.—Appendages of the head of a first-instar larva; A, antenna; B, right mandible; C, labrum, ventral view, showing the position of setae and punctures

Homology of head setae (fig. 20, A and B).—The Epistoma bearing two pairs of setae (E^1 and E^2); the distance between E^2 on either side twice that between E^1 and E^2. Frontal punctures (F^a) close together near the lower central margin of the frons. Frontal setae (F^1) a little anterior to F^a. This migration of the frontal setae from halfway up on the frons, as shown in the first instar,

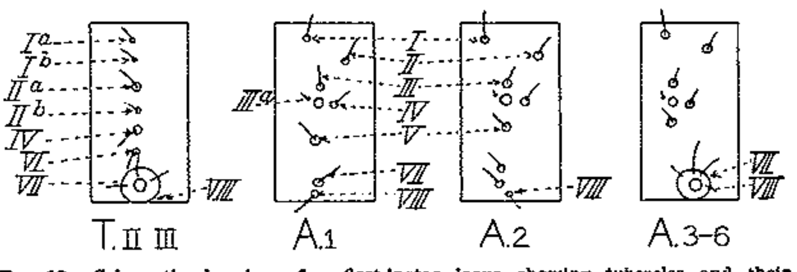

FIG. 12.—Schematic drawing of a first-instar larva showing tubercles and their position

to the present position has occurred gradually through the different instars, apparently due to the shortening of the frons. The distance between F^a on either side equal to that between F^a and F^1. Distance between F^1 and adfrontal setae (Adf^1) somewhat less than that between the two adfrontal setae (Adf^2

and Adf^2). Adf^1 posterior to the beginning of the longitudinal ridge (*LR*). Adfrontal puncture (Adf^a) slightly anterior to the beginning of longitudinal ridge. Anterior setae (A^1, A^2, A^3) arranged in form of a right-angled triangle, with A^1 and A^2 forming the base and A^2 and A^3 forming the perpendicular. Distance between A^1 and A^2 about half that between A^2 and A^3; A^2 short, A^1 and A^3 long. Posterior seta 1 (P^1) on a level with Adf^2. Posterior seta 2 (P^2) posterior to P^1, the distance between the two being equal to that between Adf^1 and P^1. Posterior puncture (P^a) on level with upper angle of frons, remote. P^1, Adf^1 and Adf^2 equidistant. Lateral seta (L^1) remote from P^2 almost on a level with P^2. Lateral puncture (L^a) postero-ventrad of its seta. Ocellar setae (O^1, O^2, and O^3) arranged in form of triangle, O^1 antero-ventrad of ocellus IV, O^2 almost directly ventrad of ocellus I, O^3 remote and postero-ventrad of ocellus VI, and O^a lying between O^3 and ocellus VI, but nearer to the ocellus than to the seta. Genal seta (G^1) antero-ventrad of O^3 and the puncture G^a postero-dorsad of G^1. Subocellar setae (SO^1, SO^2, and SO^3) present arranged in form of a triangle, SO^2 posterior and approximate to ocellus V, SO^3 postero-ventrad of SO^2, SO^1 ventrad of ocellus V. Subocellar puncture (SO^a) anterior and approximate to SO^1. Several small punctures (*X*) posterior to P^2.

FIG. 13.—The fall army worm; newly hatched larva, or worm. Greatly enlarged. (Walton and Luginbill)

FIG. 14.—Mature larva of the fall army worm. (Walton and Luginbill)

FIG. 15.—Head of larva of the fall army worm, front view. Greatly enlarged. (Walton and Luginbill)

Homology of body setae (fig. 21).—Prothorax: I^a, I^b, II^a, and II^b on the shield, the two former on the cephalic margin and the two latter on the caudal margin of the shield; II^a nearer the meson than I^a; I^c and II^c on plate immediately below shield, I^c small; IV and V approximate, cephalad of the spiracle; IV small; VI composed of two setae ventrad of the spiracle; VII represented by a number of setae around the base of the leg; VIII near the ventromeson caudo-ventrad of the base of the leg.

Mesothorax and metathorax: I^a near the dorsomeson, small; I^b laterad of I^a, large; II^a laterad of I^b, large; II^b laterad and slightly cephalad of II^a, small, fine, originating from a papilla, the surrounding area black; III ventrad and slightly caudad of II^b; IV cephalad and slightly ventrad of III; V ventrad of IV, small, its tubercle touching that of IV; VI ventrad of III, remote; VII and VIII as in previous stages.

First abdominal segment: I near the dorsomeson; II caudo-laterad of I; III dorsad of the spiracle and approximate to it; III^a cephalad of the upper corner of the spiracle, small; IV caudad of the spiracle and approximate to it; V ventrad of the spiracle, remote; VI caudo-ventrad of V; VII composed of a primary seta ventrad of VI and a secondary one cephalad and slightly laterad of the primary one, the secondary seta being small; VIII near the ventromeson.

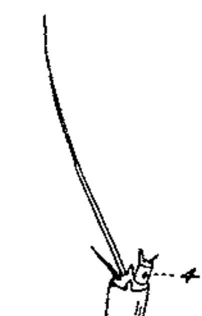

FIG. 16.—Antenna of a sixth-instar fall army worm

Second abdominal segment: Homotypy of setae as in preceding segment, except that another secondary seta of VII is perceptible cephalo-ventrad of the primary one and the other secondary seta is now ventrad of the primary seta.

Third to sixth abdominal segments, inclusive: Homotypy of setae as in second abdominal segment, but VII now situated on proleg, on its lateral face; VIII on the inner face. Crochets arranged in a mesoseries, hooks uniordinal. Number of crochets: First pair of legs 16 to 21; second pair of legs 16 to 22; third pair of legs 17 to 23; fourth pair of legs 19 to 24.

Seventh abdominal segment: I, II, III, and IIIa arranged as before; IV has migrated to a point caudo-laterad of the spiracle, remote; V as before; VI ventrad of V, distant; VII composed of only the primary seta, which is ventrad of VI; VIII as before.

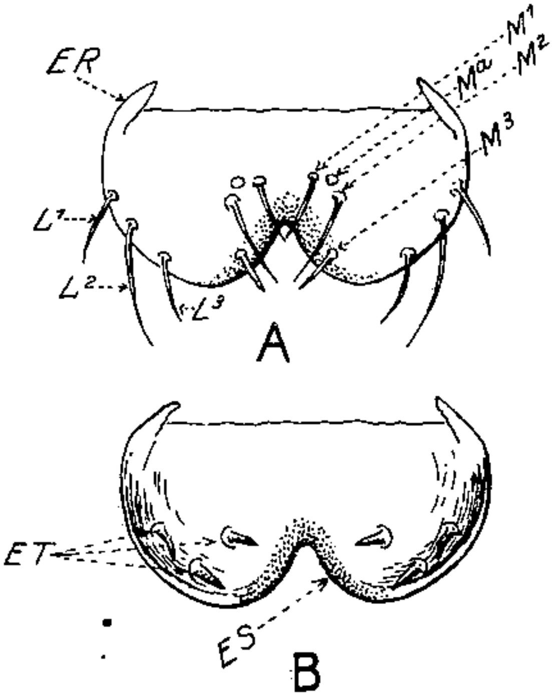

FIG. 17.—Labrum of a sixth-instar fall army worm: A, dorsal view; B, ventral view or epipharynx

Eighth abdominal segment: I as before; II caudad of I; III and IIIa as before; IV has migrated part way back to its original position caudad of the spiracle, lower left corner; V ventrad and slightly cephalad of the spiracle, distant; VI caudo-ventrad of V, distant; VII ventrad of VI; VIII as before.

Ninth abdominal segment: II near the dorsomeson; I cephalo-laterad of II; IIIa cephalo-laterad of I, minute; III in position as before, small, resembling its homotype on the thorax; IV and V united ventrad of III; VII caudo-ventrad of IV; VIII as before.

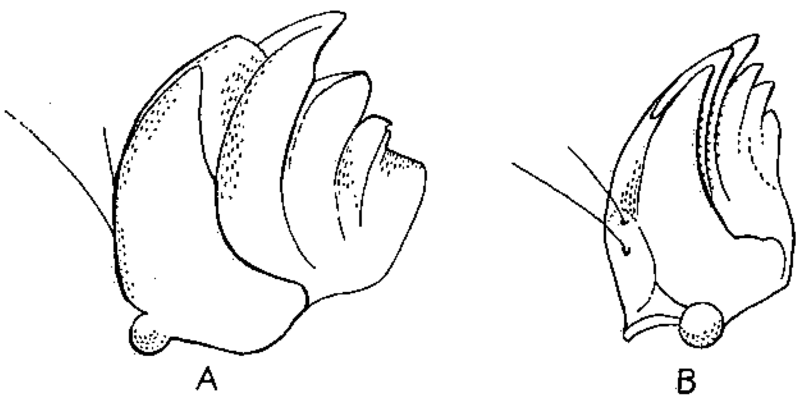

FIG. 18.—Mandible of a sixth-instar fall army worm: A, ventral view; B, side view

Tenth abdominal segment: Supplied with a number of setae on plate on either side of meson, one on fleshy protuberance caudad of each proleg, and a number of setae around the base of each proleg. Number of crochets 20 to 26.

FIG. 19. — Maxillae and labium of a sixth-instar fall army worm

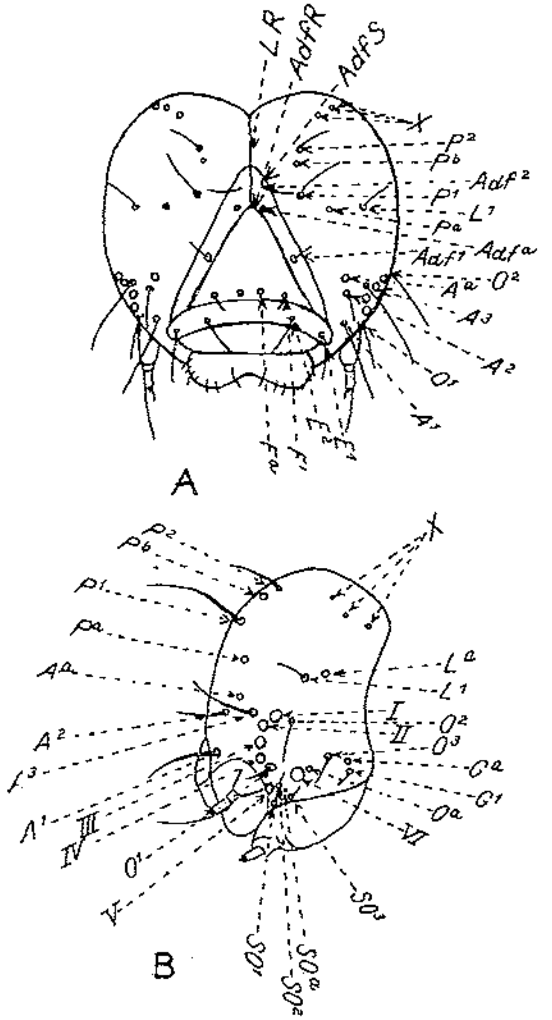

FIG. 20.—A, head capsule of a sixth-instar fall army worm, showing position and arrangement of setae and punctures; B, lateral view of same

DESCRIPTION OF PUPA

(Figs. 22, 23, and 24)

Dark reddish brown, darker on the prothorax, black immediately before emergence of the adult; labrum separated from the clypeus by distinct suture, quadrate; fronto-clypeal suture not distinct; labial palpi visible, about one-fourth length of maxillae; mesothoracic wings reaching to caudal end of fourth abdominal segment; metathoracic wings not visible on the venter; maxillae reaching almost to tip of wings; prothoracic legs over half as long as maxillae, their femora exposed; mesothoracic legs a trifle shorter than maxillae; metathoracic legs showing caudad of maxillae not projecting from caudal margins of wings; antennae a little shorter than mesothoracic legs; sculptured eyepiece somewhat broader than the glazed eyepiece; invaginations of the tentorial arms distinct; vertex narrow on the meson, broader on the sides; mesal length of prothorax one-half that of mesothorax; mesal length of metathorax one-fourth that of mesothorax; cephalic portion of the fifth, sixth, and seventh abdominal segments and the same portion of the fourth abdominal segment on the dorsum finely and densely punctured; area around the spiracles slightly elevated, blackish; caudad of each spiracle is a shallow cavity; spiracles ellipsoidal; mesothoracic spiracle extending over half the length between the antenna and the meson, the area blackish; cremaster consisting of two short, stout, blunt spines; genital opening of female simple, slitlike, apparently situated on the eighth abdominal segment, the cephalic margins of the ninth and tenth segments curving strongly forward toward the genital opening in this sex; genital opening of male simple, slitlike, on the ninth abdominal segment on slight elevation.

Length from 14.7 to 17.4 mm. Greatest width 4.5 mm.

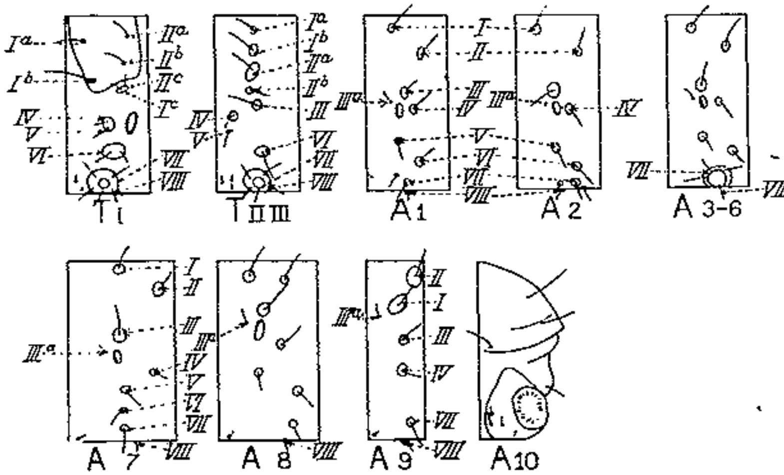

FIG. 21.—Schematic drawing of a sixth-instar fall army worm, showing tubercles and their arrangement

ADULT

(Figs. 25, 26, and 27)

The fall army worm (*Laphygma frugiperda* S. and A.) belongs to the family Noctuidae or owlet moths, order Lepidoptera. This is the largest of all of the families of the Lepidoptera and includes a number of species that are very destructive to cereal and forage crops. Among the most important of these are the true army worm (*Cirphis unipuncta* Haw.), corn earworm (*Heliothis obsoleta* Fab.), cotton worm (*Alabama argillacea* Hübn.), and others.

The first specific description of the adult, which was made by Smith and Abbot (*51, p. 191*), is very brief and reads as follows:

> Ph. *Noctua* spirilinguis cristata, alis deflexis: primoribus fusco nebulosis punctis duobus ocellaribus fuscis litura intermedia maculaque ad apicem alba.[a]

The description made by Guenée (*25, p. 157*) under the name of *Laphygma macra* was more at length and explicit, but it is evident that he did not recognize the sexes. Riley (*45*), in describing the species under the name of *Prodenia autumnalis* with the varieties *fulvosa* and *obscura*, appeared to be aware of the marked differences in coloration among the moths, but considered these as varietal rather than as secondary sexual characters. Hampson (*26, p. 262*) was first to recognize that

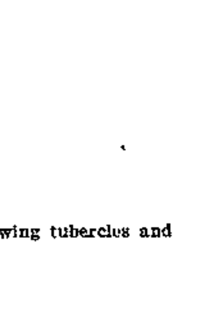

FIG. 22.—Pupa of the fall army worm. About twice natural size. (Walton and Luginbill)

[a] Phalaena. Crested noctuid with spiral tongue, wings turned downward, fore wings with two smoky fuscous round spots; a streak between them and spot at apex white.

the differences in color pattern were mainly due to sex. His descriptions of this species, based on specimens taken in North America, South America, and the West Indies, are very thorough and therefore are used in this bulletin. The figures, however, are original, as are the notes pertaining to the structure of the genitalia. Hampson did not take the genitalia into consideration in his descriptions, and, according to Carl Heinrich, these have characters of great specific and occasional generic value.

Hampson's description (*26, p. 258*) of the genus Laphygma follows:

Genus Laphygma Guenée.—Proboscic fully developed; palpi upturned, the 2nd joint reaching about to middle of frons and moderately scaled, the 3rd short; frons smooth; eyes large, round; antennae of male minutely serrate or ciliated; thorax clothed almost entirely with scales, the prothorax without crest, the metathorax with spreading crest; tibiae moderately fringed with hair; abdomen with dorsal crest at base only. Fore wing with the apex rectangular, the termen evenly curved and hardly crenulate; veins 3 and 5 from near angle of cell; 6 from upper angle; 9 from 10 anastomosing with 8 to form areole; 11 from cell. Hind wings with veins 3, 4 from angle of cell; 5 obsolescent from just below middle of discocellulars; 6, 7 from upper angle, 8 anastomosing with the cell near base only.

Laphygma frugiperda SMITH and ABBOT.—*Male.*—Head and thorax ochreous suffused with reddish brown; palpi with blackish patch at side of 2nd joint; frons with blackish bar above; vertex of head suffused with fuscous; tegulae with fuscous patches; pectus whitish; fore coxae and femora suffused with

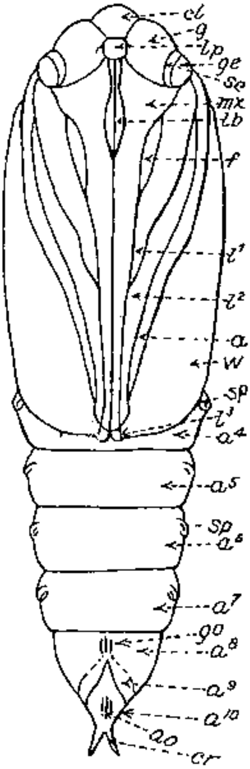

FIG. 23.—Pupa of *Laphygma frugiperda*, showing its structure. Explanation of symbols applied to pupa: *a*, antenna; a^4, abdominal segment 4; a^5, abdominal segment 5; a^6, abdominal segment 6; a^7, abdominal segment 7; a^8, abdominal segment 8; a^9, abdominal segment 9; a^{10}, abdominal segment 10; *ao*, anal opening; *cl*, clypeus; *cr*, cremaster; *f*, femur of prothoracic leg; *g*, gena; *ge*, glazed eye; *go*, genital opening (♀); *l*, prothoracic leg; *l²*, mesothoracic leg; *l³*, metathoracic leg; *lb*, labrum; *lp*, labial palpi; *mx*, maxilla; *sc*, sculptured eye; *sp*, spiracle; *w*, wing

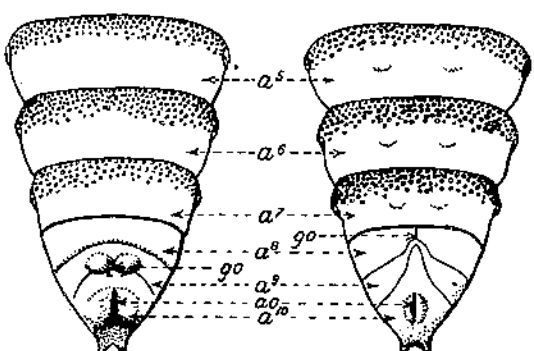

FIG. 24.—Comparison of terminal segments of male and female pupae of the fall army worm to show sexual differences

fuscous; abdomen ochreous white suffused with reddish brown leaving slight pale segmental lines, the anal tuft tinged with rufous. Fore wing ochreous whitish suffused with fuscous and reddish brown, the inner area paler; subbasal line represented by double oblique dark striae from costa; a black streak below base of cell curved up to cell at extremity; a minute whitish spot defined by black on outer side in cell before the antemedial line, which is indistinctly double, oblique, waved, somewhat bent outwards in submedian fold; claviform represented by a diffused brownish streak, orbicular whitish defined by black and with pale brown centre, a whitish bar beyond it and above base of vein 2;

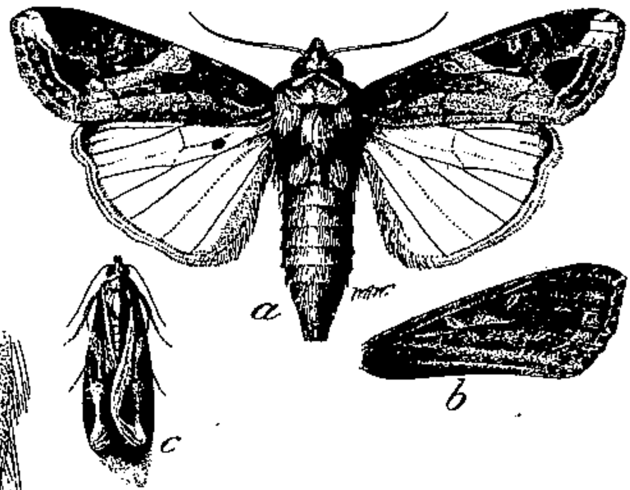

FIG. 25.—The fall army worm: *a*, male moth; *b*, right front wing of female moth; *c*, moth in resting position; *a* and *b*, about twice natural size; *c*, very slightly enlarged. (Walton and Luginbill)

reniform with black and white bar on inner side, its outer edge slightly defined by black and with irregular white marks at upper extremity; a slight white fork at bases of veins of 4, 3; an indistinct oblique waved line from lower angle of cell to inner margin; postmedial line indistinct, double, strongly bent outwards below costa, then minutely waved, incurved at discal fold and below vein 4, some white points beyond it on costa; an oblique diffused whitish shade from apex to vein 6, the whitish subterminal line arising from it, excurved at middle and bent outwards to tornus, some short black streaks before it in the interspaces at middle; a fine white line before termen with series of slight black streaks from it to the black terminal striae; cilia brownish with fine white line at base followed by a dark line. Hind wing semihyaline white, the apex suffused with brown; a dark terminal line from apex to vein 2; the underside with the costal area slightly irrorated with fuscous, a terminal series of black striae from apex to vein 2.

Genitalia (fig. 28): Uncus represented by a stout, sickle-shaped hook or spine; gnathos about as long as the uncus; harpes large and broad, the anal angles not well defined; marginal spines prominent; claspers hinged at base composed of stout hooks, one on either harpe and attached to it near the anal angle; clavus button-shaped; juxta composed of a chitinized plate in front of aedoeagus attached to articulation of harpes by two stout muscles; ampulla consists of a flap covered with numerous short spines; editum is slender, spiny at tip; peniculus oar-shaped; cornutii composed of 3 groups of several short spines each.

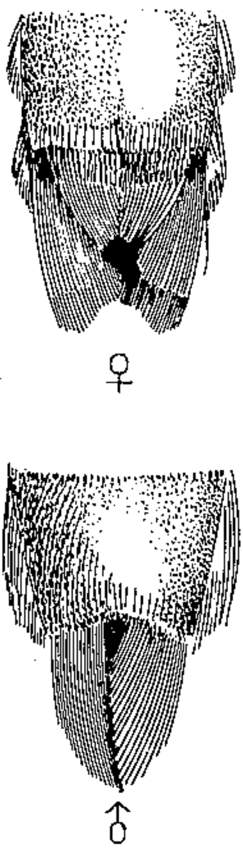

FIG. 26.—Ventral side of terminal segments of male and female moths of *Laphygma frugiperda*, showing sexual differences in the shape and size of the anal bristles

Female.—Much more fuscous brown, the costal area and veins irrorated with grey, the lines less distinct; the orbicular and reniform with slight whitish annuli, the former without pale bar beyond it and no white streak at lower angle of cell, the whitish fascia from apex obsolete.

Genitalia as represented in Figure 29.

Var. fulvosa ♂.—Fore wing somewhat more suffused with purplish, the white fascia from apex indistinct.

NUMBER OF GENERATIONS

The number of generations of this species occurring annually depends largely upon the latitude of the habitat. In the most south-

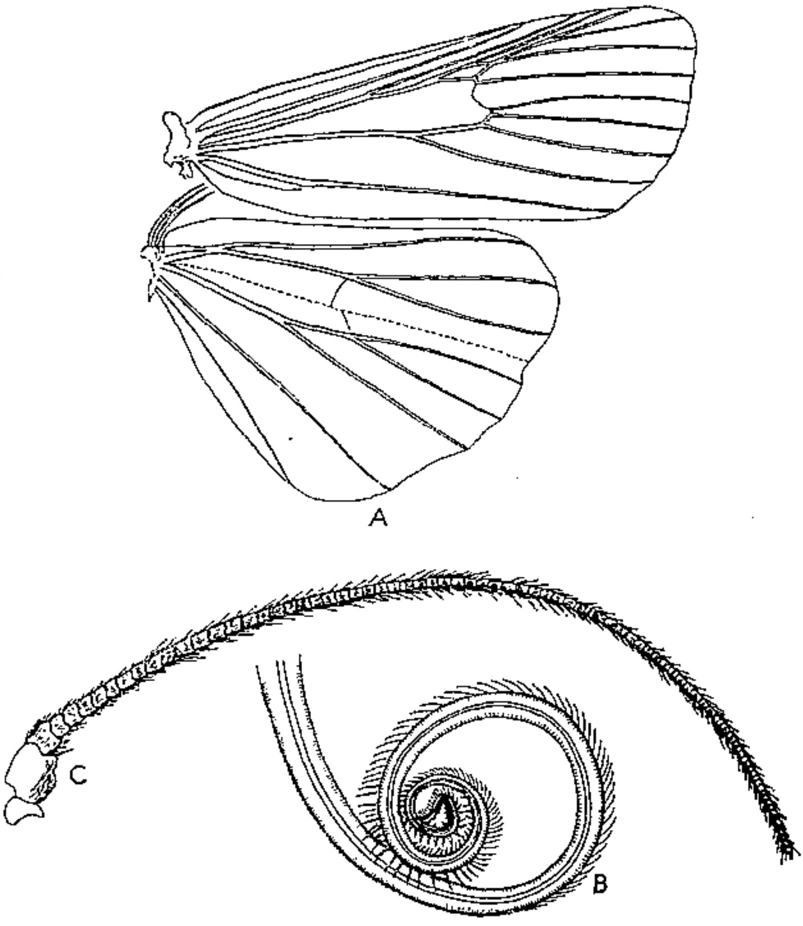

FIG. 27.—A, fore-wing and hind-wing venation of female moth of *Laphygma frugiperda*; B, proboscis of moth; C, antenna of moth

erly regions of the United States, where the species lives throughout the year, as many as six or more generations may occur. In extreme northerly regions there may be only one. At Wellington, Kans., at least two, and sometimes three, full generations have occurred in the year. In the vicinity of Columbia, S. C., there are at least three full generations, and when freezes do not occur until late fall or about the middle of November, there may be a fourth generation.

In the latitude of Columbia the first and second generation larvae are the most abundant, and if any outbreaks occur, they may be attributed to the larvae of these generations. These two generations are well defined. The second and third generations overlap considerably; in fact, it is difficult to distinguish between them. No great damage results from the larvae of the third generation, partly because of a decrease in their abundance as compared with the preceding generations and partly because the field crops at this time are maturing rapidly.

The fact that repeated inspections after swarms of second-generation moths had been observed among mature corn and weeds revealed no unusual number of larvae, leads the writer to believe that the decrease in numbers of the larvae of the third generation may be due to a southerly migration of some of the second-generation moths and a failure of those remaining to oviposit to any great extent.

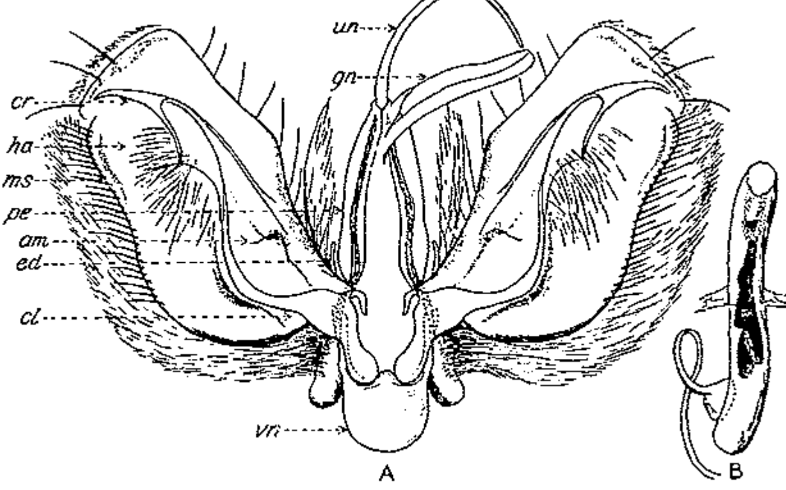

FIG. 28.—Genitalia of male *Laphygma frugiperda:* A, ventral view, aedoeagus omitted; B, aedoeagus. Explanation of symbols applied to male genital organs, A: *am*, ampulla; *cl*, clavus; *cr*, clasper; *ed*, editum; *gn*, gnathos; *ha*, harpe; *ms*, marginal spines; *pe*, peniculus; *un*, uncus; *vn*, vinculum

LIFE CYCLE

The length of the life cycle is governed largely by the prevailing temperatures, and consequently during the warmer summer months the insect completes the cycle within a much shorter period than in the spring or late fall.

In the latitude of Columbia, S. C., the average length of the cycle is about 30 days during the summer months; but in late fall the insect requires on an average about 50 days and sometimes more to complete the cycle, as is shown in Table 15. This table further shows that the length of the larval period in the summer generations in one day less than one-half of the length of this period in the fall. There is also a considerable difference in the length of the pupal periods in the summer generations and fall generations. In the case of adults issuing in midwinter, it is quite likely that the time required to complete their cycle exceeded 60 days.

At Brownsville, Tex., the summer cycle extends over a period of about 25 days, while the spring and fall cycles require a much longer period.

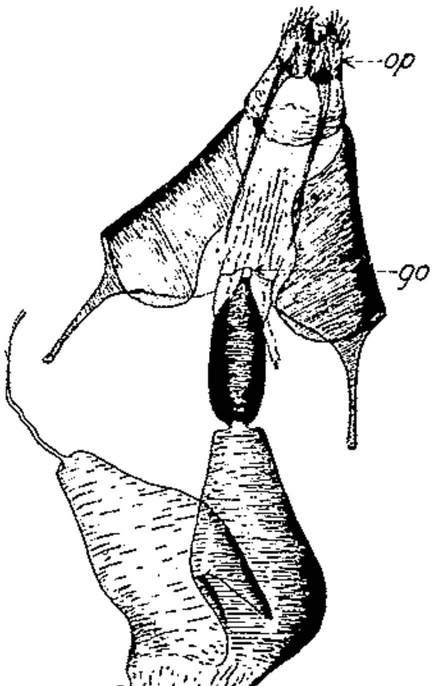

FIG. 29.—Genitalia of female *Laphygma frugiperda*: *op*, ovipositor; *go*, genital opening

TABLE 15.—*Average duration of the life cycle of Laphygma frugiperda during summer and fall at Columbia, S. C.*

Period or stage	Generations	
	Summer	Fall
	Days	*Days*
Period between emergence and oviposition	3	4
Egg stage	3	3.5
Larval stage	14	29
Pupal stage	10	13.5
Total	30	50

In its most northerly range, where the insect has only one generation, the life cycle requires a period of approximately 50 to 60 days. The cycle is somewhat longer than at Columbia, S. C., for the same time of the year, thus showing the influence of temperature.

HIBERNATION

Although various writers have expressed their belief that this species apparently passes the winter in limited numbers in northerly regions invaded by the insect, nothing definite was known about the northern limit of hibernation prior to 1916. In the preceding year (1915) large collapsible cages (fig. 30) 8 by 4 by 4 feet were constructed. The framework of the cages was made of wood and covered with 18-mesh galvanized-wire cloth. In the fall of 1915 these cages were erected at different points in South Carolina, Georgia, and Florida over soil which was seeded to grain. Figure 31 shows the points at which the cages were placed. Immediately before winter began they were stocked with a large number of larvae and pupae. The cages were examined in the early spring of 1916, and no stage of the insect could be found in any of the cages except the one located in southern Florida, where live adults and some live pupae were obtained.

During the fall of 1916 the Georgia and South Carolina cages were again stocked with larvae and pupae of the insect. Examination of the cages early the following year (1917) did not reveal any of its life stages in any of the cages in that region. Unfortunately the Florida cages could not be taken care of at that time, and therefore the data for that region are lacking.

As might be expected, because of the fluctuating weather conditions in the Southeast, the line marking the most northerly region in which the insect may survive the winter varies somewhat from year to year. It is possible that during exceptionally mild winters the species survives in the area along the north coast of the Gulf of Mexico.

According to Hinds and Dew (*31*), it is possible that the insect survives in the pupal stage in southern Alabama during some seasons. In the latitude of Columbia, S. C., and Greenwood, Miss., larvae may be found in all instars in the field until succulent vegetation is killed by frost. The date for killing frost varies somewhat from year to

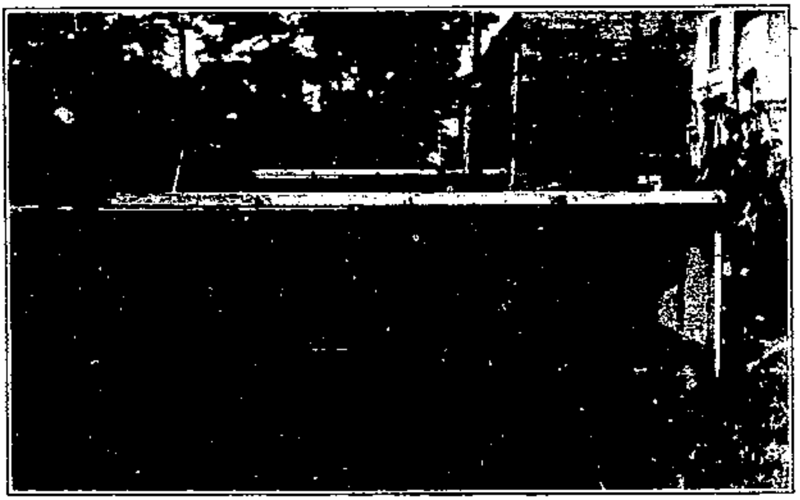

FIG. 30.—Cage of type used to determine the most northern limit at which the fall army worm may live through the winter

year. However, freezes heavy enough to kill off tender vegetation and the larvae feeding thereon usually occur in early November. No larvae have ever been taken in the field later than the middle of that month, with one exception, namely, when Samuel Blum found a full-grown larva in the field on December 24, 1920.

Observations to investigate into the possibility that the species survives the winter at other points invaded by the insect have been made by other observers in the Bureau of Entomology. Living larvae were collected in the field at Nashville, Tenn., and Wellington, Kans., until the first week in November, but subsequent to that date none were found. Consignments of pupae from Ohio and Missouri were sent to the Greenwood, Miss., station during the late fall of 1913 and placed in wire cages under natural conditions. When the cages were examined the following spring the pupae were all dead except one, which proved to be a species other than Laphygma.

R. J. Kewley, at College Park, Md., in 1914 observed live pupae but no larvae in a field in early December, but the following spring the pupae were all dead and desiccated. In cage experiments at the same place Kewley observed that moths issued from pupae in November and December and that other pupae of the same lot were found dead the following spring.

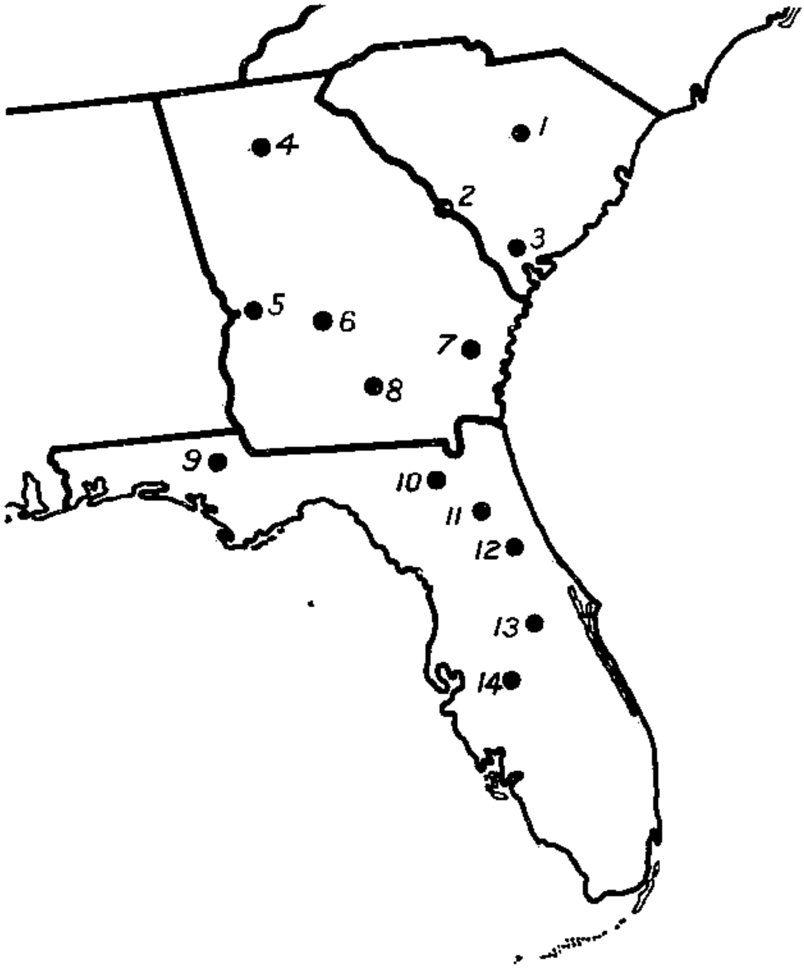

FIG. 31.—Points in South Carolina, Georgia, and Florida at which experiments were conducted to determine the northern limits where the insect may survive the winter: (1) Columbia, S. C.; (2) Augusta, Ga.; (3) Ridgeland, S. C.; (4) Decatur, Ga.; (5) Columbus, Ga.; (6) Cordele, Ga.; (7) Jesup, Ga.; (8) Valdosta, Ga.; (9) Bonifay, Fla.; (10) Lake City, Fla.; (11) Gainesville, Fla.; (12) Green Cove Springs, Fla.; (13) Orlando, Fla.; (14) Wauchula, Fla.

G. G. Ainslie and W. H. Larrimer observed larvae to be alive in rearing cages at Nashville, Tenn., as late as December 8 in 1912, when a temperature at 20° F. proved fatal to them.

W. J. Phillips observed larvae pupating late in the fall at South Bend, Ind. The following spring many dead but no live pupae were found. In some instances larvae were found dead in their burrows.

Henry Fox observed larvae pupating in pot cages at Lafayette, Ind., late in the fall of 1912, but the following spring none were alive. Live larvae were observed by Fox as late as the first week in October at Lafayette.

On October 21, 1912, E. H. Gibson visited an alfalfa field at Latonia, Ky., and found dead larvae lying in large numbers on the ground. Heavy frosts had occurred for two nights previously, following an all-day rain. All of the pupae examined were dead except two, and those were about 1 inch under ground. The dead pupae were situated very close to the surface of the soil and in most cases were abnormally expanded and much bloated in appearance.

R. N. Wilson observed larvae of all sizes feeding on corn in a field near Fort Myers, Fla., on February 15, 1916, which indicates that there is no cessation in the activity of the species in this latitude (about 27° N.), but that it is active continuously throughout the year.

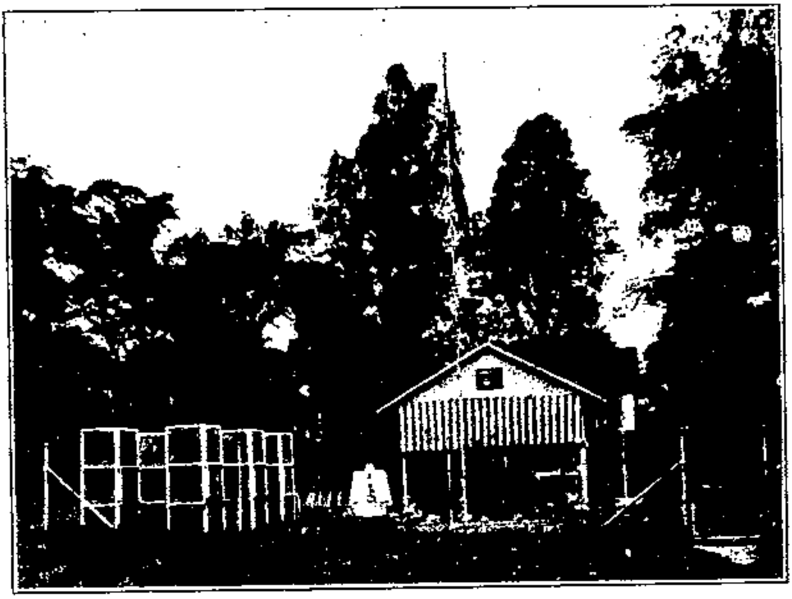

FIG. 32.—Outdoor breeding shelter or insectary at Columbia, S. C., in which studies of *Laphygma frugiperda* were conducted. (Luginbill and Beyer)

In the insectary at Columbia (fig. 32) pupae have been kept alive under conditions similar to those in nature from fall until February of the following year, when they were killed by a sudden heavy freeze (fig. 33). Had the weather continued moderate, the pupae might have produced moths the latter part of the winter. However the moths would no doubt have died before reproducing, for it has been observed repeatedly that moths emerging during the winter did not mate or lay eggs. Moths issuing during the winter were extremely inactive, often remaining at the place of issuance until overtaken by death. When disturbed they scarcely moved, and when placed on their backs they were unable to regain their normal position. It therefore seems that failure to survive the winter is due not only to the fact that pupae and larvae may be killed by frost, but that moths issuing during moderately warm days in early winter (mean temperature about 50° F.) die without reproducing, and thus it is impossible for this species to survive in the greater part of the region in the United States which is invaded almost yearly. This insect really has no definite period of hibernation. It is to be remembered that it is a tropical species. In regions where it survives the winter, it breeds continuously, and is more or less active throughout the year. It is not improbable that the species, by its annual attempts to invade northerly regions, may in time produce a strain which will become hardier and able to survive, especially in that part of the United States where the winters are not severe.

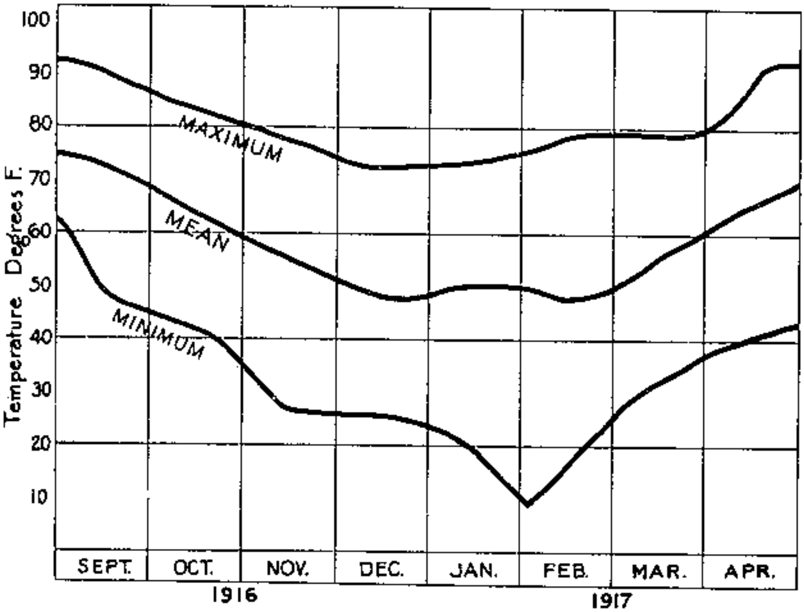

FIG. 33.—Prevailing temperature at Columbia, S. C., from September, 1916, to April, 1917, inclusive

DISSEMINATION

The studies conducted indicate that this species is disseminated every year chiefly by flights of the moths. Moths flying about in swarms among forage and other plants on a particular day, have been known to disappear entirely by the following day. The adults presumably took wing en masse and migrated to other regions, as it seems very unlikely that all of such moths would die within a single day.

As has been mentioned elsewhere, the only regions in the United States in which the insect is definitely known to survive the winter are southern Florida and southern Texas. Every year the insect advances northward from its winter quarters through flights of the moths. The moths advance an uncertain distance, alight, and produce a generation of the insect. The adults arising from this generation proceed farther north to repeat the operation, so that by fall the insect usually has spread over a large part of the eastern United

States. The distance covered by the adults at a single flight depends upon various factors, such as prevailing winds, temperature, and food supply. It appears that the distance covered by the spring generation in Florida is not so great as that covered by the summer generation farther northward. The early summer generation sometimes becomes distributed throughout Alabama in one flight.

The course of migration depends largely upon prevailing winds or is importantly influenced thereby. The insect always appears in western Florida before it makes its appearance in northern Florida, indicating that the species first takes a northwesterly course in that State. In Texas the insect takes a northeasterly course, following the coastal plain, as well as a northerly one until it reaches the Mississippi River, when the general course is north, or following the valley of that river and its tributaries. The southeastern States

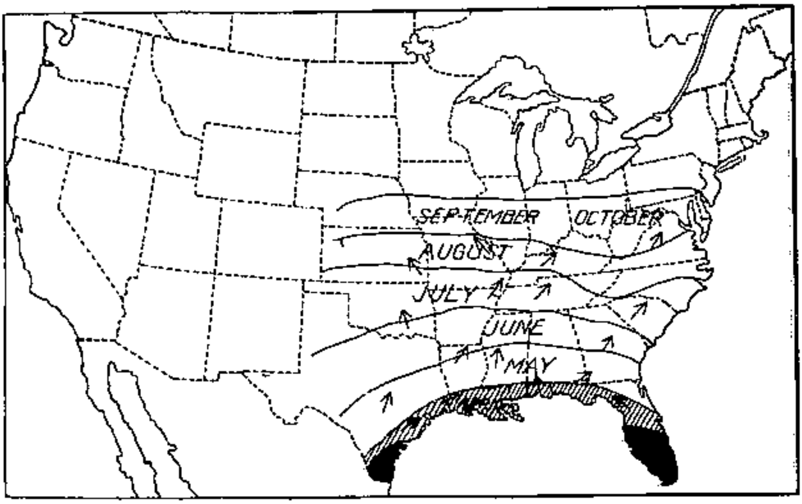

FIG. 34.—Map showing the progress of *Laphygma frugiperda* northward in a normal year

apparently are invaded by migrants from the Florida district, the general course east of the Appalachian Ranges being northeasterly. The insect appears in north-central Georgia considerably earlier than in central South Carolina, which indicates the northeasterly trend of the species in that region. West of the Appalachian Ranges the general course is north, following the valley of the Mississippi River and its eastern tributaries, spreading out and infesting the surrounding country. During a normal year or during a year when no general invasion occurs the insect confines itself almost exclusively to the lowlands along streams and rivers and other swampy places.

The progress of the insect northward during a normal year is plotted in Figure 34. This is based on observations made on the appearance of the insect, extending over a period of years at various points in the South. The area invaded embraces chiefly the South from southern Texas and Florida to Maryland and Nebraska on

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the north, including the southern portions of Illinois, Indiana, and Ohio, the insect breeding mainly in the Ohio Valley. Migrant moths arrive in northern Florida in late April or early May; in north-central Georgia in early June; in central South Carolina June 15 to July 1; in central Tennessee about the 15th of July; in southeastern Kansas during late July; in the Ohio Valley and Maryland during August and September. During a normal year the movements northward are not so rapid and the area of the country invaded is not so large as during a year when a general invasion occurs. Figure 1 shows the distribution of the insect during a general outbreak, such as occurred in 1912.

The insect appeared at Tempe, Ariz., from July to September in 1913 and 1914.

Locally, the insect is dispersed by other agencies as well as by flight. Freshly hatched larvae hatching from eggs deposited on tall plants, upon lowering themselves to the ground by their threads, may be blown some distance by winds and scattered over a considerable area. Larvae of this species have great power of endurance and are able to crawl for considerable distances. When the forage has been devoured in a field, the larvae march in an army, invading other fields and often crossing hard roads while exposed to a blazing sun.

OTHER INSECTS OFTEN CONFUSED WITH THE FALL ARMY WORM

Among the principal insects sometimes confused with the fall army worm, especially in the South, are the true army worm (*Cirphis unipuncta* Haw.), cotton worm (*Alabama argillacea* Hübn.), and not infrequently the corn earworm, sometimes known as the cotton boll worm (*Heliothis obsoleta* Fab.). There are marked differences in the habits and seasonal history as well as in the taxonomy of these species.

The true army worm is a resident throughout that part of the United States in which the fall army worm is a migrant. Often it is a serious pest. It is in fact more of a pest in the Northern, Middle-Western and Eastern States than in the Southern States, although sometimes considerable damage is done by this insect in the South. Outbreaks of the true army worm usually occur during the early part of the summer, while in the case of the fall army worm, most of the injury is done during the latter half of the summer and early fall. Although the true army worm and the fall army worm have many food plants in common and are often taken side by side from the same plants, the former species seems to have a wider range of food plants, and when forage is devoured in one place moves forward in a definite direction and invades other fields. In the case of the fall army worm, when its food supply has given out in one place it spreads out in all directions. The fall army worm is particularly addicted to lowlands, while the true army worm is to be found on uplands as well as lowlands.

Pupation of both species takes place in the soil. The true army worm is readily distinguished from the fall army worm by color and structural characters. Its body is smooth and lustrous, its tubercles are inconspicuous, and the color pattern is composed of alternate stripes of light and dark colors, with greenish to reddish brown in between, the stripes being very narrow. The body of the fall army worm is somewhat rough, not shining, and its tubercles are conspicuous, black, and supplied with conspicuous stiff setae. The color pattern is composed of a grayish dorsum, traversed with three whitish longitudinal lines, the pleurons bearing dark and light bands, a pair on either side. The head of the true army worm is greenish brown, mottled with black, while the head of the fall army worm is almost black, mottled with patches of light color, especially on the sides back of the eyes. The adfrontal region and the longitudinal ridge on the head of the fall army worm have a white color which stands out very conspicuously against the dark color of the remainder of the epicranium and appears as an inverted Y. In the true army worm this region is of the same color as the rest of the head.

The cotton worm (*Alabama argillacea* Hübn.) is exclusively a cotton pest and is believed not to feed on any other plant. It is a migrant, like the fall army worm, appearing later in the season, in the main cotton-growing region, than does the fall army worm. It also moves forward in a fixed direction, like the true army worm, when its food supply diminishes, more markedly than the fall army worm. The cotton worms may spread over a cotton field with great rapidity and devour every leaf on the plants. In this respect this insect differs greatly from the fall army worm, as the latter species rarely injures cotton. In fact, it is only in cases where the infested grass among cotton is consumed before the larvae are mature, that cotton is injured to any extent. The cotton worm spins up on the leaves and transforms there. The fall army worm pupates in the ground. The larvae of the cotton worm are yellowish green in color, sometimes without any other conspicuous markings whatever. However, they most often show a dark longitudinal dorsal stripe with a light line through its center and another on either side. The tubercles are quite conspicuous.

The corn earworm (*Heliothis obsoleta* Fab.), when feeding on the ear of corn in the husk, is often mistaken for the fall army worm, which has a similar feeding habit. The two species are sometimes found together in the same ear. Larvae of both species also feed in the "buds" of young corn before it is in tassel and for this reason often may be confused. Heliothis larvae sometimes do great damage to vetch in the South during the spring of the year, before Laphygma has made its appearance, and when thus feeding they adopt the army-worm habit. The insect is a permanent resident, and transformation takes place in the soil. There are a number of generations per year. The larvae are variously colored, ranging from green to almost black, and between these extremes are found many patterns made up of light and dark bands. The tubercles are conspicuous and black, each supplied with a stiff hair. The skin of the larva appears roughly granulated, and the head is reddish brown, mottled with pale patches.

All three species previously mentioned have the cannibalistic habit as strongly developed as has the fall army worm and feed on larvae of their own kind, as well as on soft-bodied larvae of other species.

REARING METHODS

Larvae of the fall army worm have been reared in many kinds of cages, such as tin ointment boxes, glass tubes, and jelly glasses. In spite of such varying conditions these larvae exhibit very slight susceptibility to attack by fungi, parasites, and bacterial diseases. Rearings on an extended scale have been made in individual tin ointment boxes, but such rearings require much of the experimenter's time, and unless studies of the individual or its parasites are desired, *Laphygma frugiperda* may be reared quite readily in large lantern-globe pot cages. Where these are used it is very necessary that they be bountifully supplied with forage not only as subsistence for the caterpillars but also as protection for the larvae, or to eliminate the dangers of cannibalism. At Columbia, S. C., as many as 100 larvae have been reared in one of these lantern-globe cages from egg to maturity. A large handful of fresh crabgrass or other forage was placed in the cage with the young larvae each day. The foliage of the old grass was eaten, but the larger stems remaining afforded the larvae a place of concealment from each other. By the time the larvae reached maturity the cages were almost full of grass and grass stems, and the grass on the bottom was beginning to decompose. Many of these larvae pupated in this decaying grass, while others entered the soil underneath. These cages were kept in the insectary. (Fig. 32.)

In conducting molting experiments glass test tubes stopped with absorbent cotton were used. These were supplied with leaves of fresh crabgrass each day or as needed. Since the appearance of the larva is an index of the occurrence of ecdysis, the transparent glass tubes were found superior to other receptacles for these studies. By this method the experimenter can observe the insects with an ordinary hand lens and does not have to remove the specimens from the tubes. A superior type of egg cage is the common small lantern-globe cage with cheesecloth top and saucer bottom.

MEANS OF REPRESSION

PREVENTIVE MEASURES

There is little doubt that serious injury to crops from this pest over a wide area could be prevented in years when a general invasion occurs, if the planters and general public would heed the call to arms in time to employ proper means to repress the invader. Such outbreaks are now fairly accurately forecasted by Federal and State entomologists, and if such warnings were heeded the insect might be checked while still confined to a small area of the country in the far South early in the year. At least there is little doubt that injury to crops in the whole South could be much lessened and in regions farther north almost eliminated. However, such methods of control, to be successful, require concerted action between entomologists and the general public and must be taken early in the season while the insect occupies only a small part of the country.

Planters in regions subject to yearly invasions, individually may prevent damage to their crops by inspecting these often during the growing season and, where any signs of larvae are present, applying means of control at once before the insect has gotten beyond control. In the greater part of the South where the fall army worm is a yearly visitor, crops subject to damage, such as grass and grasslike plants, should be inspected often during June, July, and August. In the far South injury is often done in May, but in the far North it does not occur until September and early October.

PROTECTION OF NATIVE BIRDS

All native insectivorous birds should be carefully protected, and the wanton killing of these birds should be severly dealt with by law. A large number of these birds are enemies of this and other insects, and their multiplication should be encouraged by State and Federal authorities. Birds that have become almost extinct should be given every possible chance to increase in numbers. Where necessary, special provisions should be made by Congress and State legislatures so that the work of restocking may be carried on.

CONTROL MEASURES

MECHANICAL METHODS

Various mechanical methods have been found to be of great value in destroying caterpillars, the method to be adopted depending largely upon the prevailing conditions.

BARRIERS

When the food supply has been exhausted by the worms they disperse in all directions, but they may be trapped by plowing a deep furrow at right angles to their course of advance. The larvae falling in this furrow may be killed by dragging a log through it, as shown in Figure 35. Shallow holes may be dug at intervals in the furrow, and if the soil is only slightly permeable some petroleum or kerosene may be poured into them. This will kill the caterpillars in a very short time after they reach the fluid. The furrows should be kept free from rubbish so that the larvae will have no means whereby they may cross to the opposite side.

Where a furrow is not possible a thin line of liquid coal tar placed a little distance ahead of the invading army keeps the larvae from entering the neighboring fields.

CRUSHING THE LARVAE

In smooth lawns the larvae may be destroyed by using a steel lawn roller. This method also answers for field use, where a large field roller is obtainable, such as is illustrated in Figure 36, but only where the larvae are crossing a smooth, hard surface, such as a road. Steel rakes may also be employed in some cases with success in destroying caterpillars. In gardens, should it seem impracticable to spray, the worms may be shaken from the plants into receptacles containing small quantities of kerosene.

CHEMICAL MEASURES

The chemical measures employed to kill larvae may be divided into three classes—sprays, baits, and dusts. Each of these methods, when applied correctly under proper conditions, is successful. However, not all of them can be utilized under all conditions. It depends largely upon the character of the crop involved which of the three methods of combat is preferable.

SPRAYS

Various arsenical poisons have been tested against the fall army worm, each one of which has been found to give a certain amount of

FIG. 35.—Ditch prepared to entrap fall army worms. A log dragged back and forth through the ditch crushes the worms that have fallen into it. (Walton)

control. However, as may be imagined, an omnivorous insect like *Laphygma frugiperda* can not be reached with every arsenical with equal success. An insecticide applicable under one condition may not be employed with equal success under other conditions.

Lead arsenate.—Good results were obtained with lead arsenate (in powder form, 1 pound in 50 gallons of water, or in paste form, 2 pounds in 50 gallons of water) for larvae feeding on crabgrass and similar plants. When spraying corn, double the quantity of arsenate to the same quantity of water should be used, and the spray should be applied so as to force the fluid deep down into the buds of the plants in order to reach the larvae.

Paris green (aceto-arsenite of copper).—This arsenite has given satisfactory results in control work against Laphygma and in some instances is to be recommended because it is slightly more toxic than the other poisons. It is to be especially recommended when the outbreak occurs in grasses and other forage plants that have no great value. These may be sprayed with 2 pounds of Paris green in 50 gallons of water. Where this insecticide is to be applied to valuable forage plants, hydrated lime should be added to the mixture to prevent the burning of the plants, as Paris green is too toxic to use in its pure form or without the addition of lime. It is unnecessary to make the mixture as concentrated as that given above when useful plants are sprayed. Paris green at the rate of 1 pound in 50 gallons of water, to which have been added 2 pounds of freshly slaked lime, is the proper mixture to use in such cases.

During the great outbreak of 1912 numerous instances occurred in which the Paris green mixture applied to plants without the addition of lime resulted in serious burning of plants.

FIG. 36.—A land roller which may be used to crush larvae while they are crossing a smooth road. (Webster and Phillips)

Zinc arsenite.—A mixture composed of 1 pound of arsenite of zinc in 50 gallons of water, to which was added 1 pound of freshly slaked lime, has given satisfactory control of the insect when it was feeding down in the bud or central shoot of the corn. The spray, however, must be forced down into the buds of the plants. Hinds and Dew (*31*) recommend 1 pound of this insecticide to 80 gallons of water for plants having a broad leaf surface.

Calcium arsenate.—Since this insecticide has become popular in the South for use against the boll weevil, tests have been made to determine its efficacy against the fall army worm. It may be used in a spray mixture composed of 3 pounds of the arsenate in 50 gallons of water, to which have been added 2 pounds of hydrated lime. It is necessary to add the lime as otherwise the mixture will burn the plants. The application is made as in the case of the lead arsenate and Paris green mixtures.

Miscellaneous mixtures.—Mixtures of commercial washing powder and water, and whale-oil soap and water have also been tested, but with poor results. Great harm was done to the plants, and therefore these mixtures are impracticable for such use.

Spraying infested lawns with kerosene emulsion has been recommended by Chittenden to kill the larvae. Whenever this is done, the lawns should be thoroughly sprinkled with water a few hours after the application of the emulsion so as to prevent it from burning the grass.

Application of insecticides.—In applying the liquid insecticides any one of the commercial sprayers may be used. However, the particular type of sprayer used should be adapted to the crop that is to be sprayed. A knapsack sprayer is a convenient machine to have on hand, as it may be used in places where a larger sprayer would be unsuitable. Such a sprayer will treat only a small area with one charging. However, outbreaks usually begin in low places in fields and such areas may be treated very easily with a knapsack sprayer; it is also recommended for garden and lawn use. Portable compressed-air sprayers may be used in such places when preferred. Traction sprayers may be employed with success in alfalfa fields and in other forage crops which permit the operation of a large machine. In any spraying, care should be taken that every part of the foliage is reached, the lower leaves as well as the upper ones, because success depends chiefly upon the thoroughness of the application.

DUSTS

The recent success in poisoning the boll weevil with a dry insecticide applied by the use of a duster has added a new means of control for other leaf-eating insects. This method has been successfully used to repress the fall army worm. In certain sections of the South dusting machines now are as common as sprayers, and hence this method of fighting the fall army worm is particularly recommended in cotton-growing States. The same duster and poison used to combat the boll weevil are effective against the fall army worm.

A dusting machine of an effective type is illustrated in Figure 37. This is recommended for use where small areas are to be treated and in places where a large duster could not be used on account of the large size of the plants. Small areas of infested grass growing in low places and grass growing among tall corn may be treated very readily with such a machine, which is also adapted for use on lawns and in gardens. Where large fields are to be treated, such as alfalfa or cotton fields, which permit of the use of a larger duster, a duster of any one of the types recommended for the control of the boll weevil may be used. An example of a duster of this type is given in Figure 38.

Lead arsenate.—Lead arsenate may be applied in the powder form with a duster. In applying this poison care should be taken that the lower as well as the upper leaves are covered. The rate of application per acre depends upon the crop to be treated, but from 4 to 5 pounds per acre usually is sufficient. This insecticide should be applied while the dew is on the plants or immediately after a rain.

Good control may be obtained by applying this arsenical to young corn while the larvae are young. When larvae are nearly mature they often bore into the buds or feed in other protected places and are then more difficult to reach. Where applications of lead arsenate in the dust form have not been successful in killing the insect on corn, the lack of success may have been due to a late application after the larvae had begun their boring. Lead-arsenate dust adheres well to all parts of the young plants. When used as a spray it has been noticed that it frequently runs off the plants without wetting them.

Calcium arsenate.—On account of the fact that calcium arsenate is recommended for boll-weevil control and has been especially prepared for use in dusters, it is advisable to use it against the fall army worm, particularly in the South. However, this insecticide

FIG. 37.—A hand duster which may be used in applying calcium arsenate or lead arsenate to forage plants infested with the fall army worm. (Luginbill and Beyer)

should not be used unless it meets departmental requirements, that is, it must not have over 0.75 per cent of water-soluble arsenic pentoxide. If the mixture contains a greater percentage of water-soluble arsenic, it should either not be used at all, or, if used, it must be mixed with a carrier. However, at the present writing a satisfactory carrier has not been discovered, and such procedure is not recommended.

The best results were obtained when the arsenical was applied in the pure form. A certain amount of control was obtained when calcium arsenate was mixed with lime, but not enough to warrant its consideration. Lime acts as a repellent, and foliage treated with an arsenate containing excess lime is usually left by the larvae for foliage which has been treated with a pure calcium-arsenate dust.

In order to get the best control, this arsenate should be applied to plants while the larvae are young. When the mixture is applied after the larvae are almost mature, control is much more difficult, for at this stage the larvae often penetrate more deeply into the protected portions of the stalk. B. R. Coad, in supervising the poisoning of several thousand acres of corn in 1920, observed that in some cases there were absolute failures to control, but in the majority of cases quite satisfactory results were obtained. Coad further observed that whenever the dusting was started during the early stages of the injury, complete control was secured, and that failure seemed to be confined to cases where the injury had become exceedingly heavy before any poison was applied.

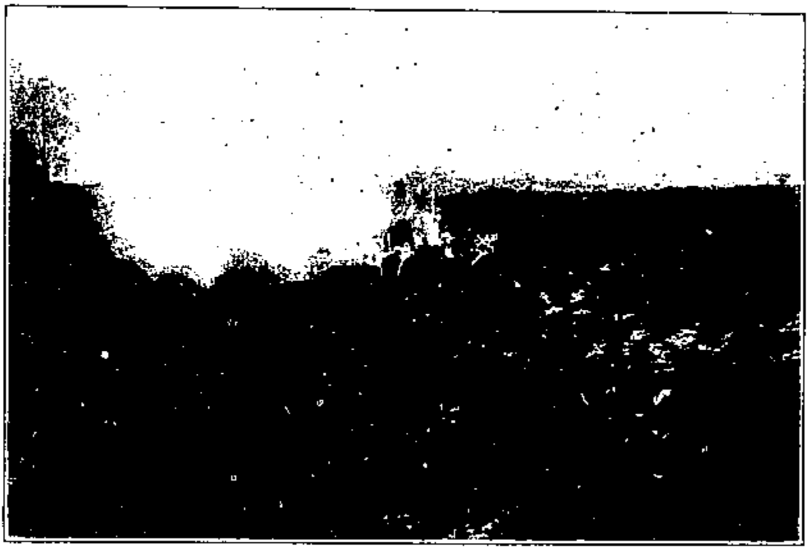

FIG. 38.—A traction duster for use in dusting cotton, alfalfa, and young corn infested with the fall army worm. (Photo by B. R. Coad)

Paris green.—Paris green as a dust may be applied undiluted on plants that have no value. It should be applied while the plants are damp. For use on plants that have food value it must be mixed with lime to prevent burning. The mixture should contain about 20 parts of lime to 1 of Paris green.

Road dust.—Smith and Abbot (*51*), as early as 1797, recommended the throwing of dirt into the infested buds of corn plants to destroy the larvae. This method is also practiced by the natives on the island of Barbados. This supposed remedy has no control value whatever.

BAITS

Where the fall army worms are feeding on small plants, such as crabgrass and alfalfa, and especially where such plants are nearly destroyed, the bait method has been found of great value in combating this insect. Experimenters are quite well agreed on the composition of this bait, their differences of opinion being mainly as to the proportion of the ingredients included in the mixture. Federal entomologists have found the following mixture to be satisfactory:

Wheat bran	50 pounds.
Paris green or white arsenic	1 pound
Low-grade molasses or blackstrap	2 gallons
Water	Sufficient to make a stiff dough.

The bran and insecticide are first mixed dry. The mixing should be done very thoroughly. The molasses should then be added and the whole again thoroughly mixed. Enough water is then added to the mixture to make a stiff dough. If preferred, lead arsenate or calcium arsenate may be used at the rate of 2 pounds to the 50 pounds of bran, instead of other arsenicals. In regions where the bait dries out readily, salt may be added at the rate of 5 pounds to 50 pounds of bran. This keeps the mixture moist and makes it more palatable. The bait should be broadcasted over the fields, the rate of application depending upon such factors as the crop infested and the abundance of the insect. Usually 50 pounds should treat at least 5 acres. No harm results in applying it at a higher rate. The bait should be applied preferably in the evening. When the worms are seeking other forage the mixture, instead of being broadcasted, may be placed in small piles short distances apart. Care should be exercised that poultry does not gain access to the baited fields, and the bran should be free from grains so to avoid killing beneficial birds. Where this mixture has been applied by hand in the buds of infested corn plants great good has also resulted.

CULTURAL METHODS

In a great many cases damage to field crops by the fall army worm could be practically eliminated if the crops were kept free from grass. In other words, if clean cultural methods were employed very rigidly by the planter, damage could be minimized. This insect is primarily a grass-feeding species and breeds in grasses wherever possible. In the South, crabgrass and other native grasses grow luxuriantly in the fields after July, especially in fields that are moist, and lowlands are frequently almost covered with such grasses. It is therefore little wonder that crops in such fields are devoured, as the infestation starts on grass, and the larvae, after consuming the grass, proceed to attack other crops. If these crops were kept free from grass, the insect would not have this invitation to enter them, but would confine itself to waste places. In the great majority of cases where cotton is damaged, the explanation is that the cotton field was full of grass which was infested at the time of cultivation, and when cultivation deprived the caterpillars of their food plant, they proceeded to the cotton. Corn is often injured in the same manner. Grass growing in the corn is first devoured, and injury to corn follows. However, during a general invasion the fields free from grass are also attacked, and at such times it is necessary to adopt other than cultural methods; but even then clean culture is helpful.

In some instances it is possible to save some of the feed value of infested crops by cutting them immediately. This is particularly true in the case of alfalfa. Whenever this crop is seriously infested it is well to cut it immediately for hay. The field should then be lightly disked immediately to kill the larvae and the pupae. If necessary, a furrow should subsequently be made around it as previously recommended. If the crop is not sufficiently developed to be cut, it may be sprayed or dusted.

Shallow cultivation of corn and cotton by means of a disk harrow after the larvae have gone down to pupate is highly recommended. Such cultivation kills numbers of pupae and exposes others which are killed by the hot sun in a short time. It has been found that pupae are killed by less than one-half hour's exposure to the sun when the soil temperature is over 100° F.

In rice fields the most important cultural remedy is flooding the rice sufficiently to cover the plants, as first recomended by Riley. Flooding drowns most of the larvae, provided the water is left on the fields for at least two days. G. E. Bodkin recommends the construction of nursery beds for rice in British Guiana, where they cultivate this crop by oriental methods. These beds permit of complete flooding to the tops of the young plants. The floating larvae may then be collected and destroyed. G. E. Smith noted the successful control of the insect on rice at Tallulah, La., by flooding.

In the wheat-growing regions of the United States visited by the fall army worm, injury to this crop may be avoided to some extent by late seeding. The date of seeding wheat in this region to eliminate injury by the Hessian fly usually will also be a safe date for seeding to avoid damage by the fall army worm, for wheat sown on a fly-free date is not of sufficient size to be damaged when the fall army worm arrives, and by the time the wheat is of fair size the caterpillars will have disappeared for the season.

NATURAL ENEMIES

The fall army worm has numerous enemies which prey upon it in all of its life stages. As has been previously mentioned, the abundance or scarcity of natural enemies to a large extent determines whether or not fall army worms become abundant enough during a season to cause destruction to crops. Local outbreaks are often controlled by natural enemies alone. It appears that a general outbreak of *Laphygma frugiperda* becomes possible only when the natural enemies of the insect have been reduced in its permanent habitat, thus permitting the insect to develop in enormous numbers in early spring.

This evidently is what occurred during the spring of 1912. The enemies were not abundant in Florida, and the pest appeared in great numbers. During the midsummer of that year the parasitic enemies were increasing in numbers. However, the insect by that time had made good progress to the northward by flight, and had invaded a large part of the southeastern United States. In July of that year the enemies were not abundant in South Carolina and other regions in that latitude but became common by late fall. The following year (1913) the enemies were common in southern Florida in February and March and throughout late spring. In South Carolina the hymenopterous and dipterous parasites were very common among larvae at Columbia during July, in a local outbreak of the species on millet. The predacious enemies were also conspicuous by their numbers. The outbreak of the species in 1912 may therefore be attributed to a large extent to the scarcity of its enemies in its permanent habitat and in other parts of that region during the early part of the year.

During an outbreak of the fall army worm in 1920 at Columbia, S. C., the only common parasites present were tachinids. Hymenopterous parasites and predacious enemies were rather scarce. As high as 33 per cent of the larvae in some instances were parasitized by tachinids. Birds, especially the English sparrow, visited infested areas and fed voraciously on the larvae.

The enemies of the fall army worm have been grouped as invertebrates, vertebrates, and diseases. In the first group are both parasitic and predacious enemies. The parasitic enemies include those belonging to the insect orders Hymenoptera and Diptera. The hymenopterous parasites represent many genera and in several instances more than one species of a single genus. The order Diptera is represented chiefly by the family Tachinidae, including a number of genera and species. The predacious enemies embrace some of the insects belonging to the orders Coleoptera, Hemiptera, and Hymenoptera; also miscellaneous enemies belonging to different orders, some of which are not insects, although closely related thereto. The vertebrate enemies consist of mammals, amphibians, and birds; the latter class embracing the wild birds and domestic fowls.

- Natural enemies
  - Invertebrates
    - Parasites
      - Hymenoptera—wasps.
      - Diptera—tachinids.
    - Predators
      - Coleoptera—beetles.
      - Hemiptera—bugs.
      - Hymenoptera—wasps.
      - Miscellaneous—arachnids, etc.
  - Vertebrates
    - Mammals—skunk.
    - Amphibians—frogs and toads.
    - Birds
      - Native—crows, larks, etc.
      - Domestic fowls—chickens.
  - Diseases.

INVERTEBRATES

HYMENOPTEROUS PARASITES

ICHNEUMONIDAE

Ophion bilineatus Say is a parasite which has been reared from Laphygma larvae at different times during the eight years preceding 1923 at the Columbia, S. C., field station and elsewhere by Federal investigators. During years when the fall army worm is abundant this parasite is very common. Larvae parasitized by it show no outward signs until pupation is imminent. The larvae enter the prepupal state and sometimes transform to pupae. The parasitized larvae are not retarded in development, as is often the case when infested with other hymenopterous parasites. The females of this Ophion prefer to sting the fourth-instar larvae, but the younger larvae are also attacked. In the latter case development of the parasite is not so rapid as is the case in older larvae. The parasites develop with the host larvae but do not issue before the prepupal or pupal stage of the host. When the parasitic larva is to emerge from the pupa of the host, the prepupa of the latter does not act normally. A normal or unparasitized prepupa, when disturbed, moves its abdomen from one side to the other with a jerky motion, no other movement taking place as a rule. When the prepupa containing a grub of *O. bilineatus* is disturbed it not only moves its abdomen from side to side but performs various contortions and rolls over when placed on a smooth surface, often drawing itself together as if affected by cramps. The color of a parasitized prepupa is somewhat different from that of a normal one, being much paler on the venter. In the majority of cases the parasitic larva emerges from the prepupal stage of the host and spins its cocoon within the cell made by the latter. In some cases, however, it emerges from the pupa of the host, boring its way out just behind the point of attachment of the wings, and spins its cocoon as before. Parasitic larvae emerging from hosts which had been under observation and whic' thus had no chance to make cells had great difficulty in spinning their cocoons. In fact, very often such parasitic larvae died, apparently being unable to construct cocoons. Cocoon construction was facilitated by placing bits of cotton or other material over them. The cocoon is pale brown and oval in outline. There is considerable variation in the length of the cocoon period. The records of 28 individuals undergoing transformation between July 19 and September 19 at Columbia, S. C., show a minimum of 12 days, a maximum of 56 days, and a general average of 19.75 days for the length of the cocoon stage. At Brownsville, Tex., Vickery observed that the cocoon period for 81 individuals was 15.1 days, at an average mean temperature of 81.09° F. (Table 16.) The average length of this period for males was 14.2 days; that for females was 15.8 days.

TABLE 16.—*Duration of cocoon stage of Ophion bilineatus Say, during May, Brownsville, Tex., 1915*

Number of individuals	Date of spinning cocoon	Date of emergence of adult	Number of— Males	Number of— Females	Days in cocoon	Tempera-ture, ° F.
6	May 17	May 31	1		14	81⅓
		June 1	2	1	15	81½
		June 2		1	16	81¼
		June 3		1	17	81⅓
25	May 18	May 31	3		13	82
		June 1	6	2	14	81⅕
		June 2	3	4	15	81½
		June 3		4	16	81½
		June 4		2	17	81⅓
		June 7		1	20	82
20	May 19	June 1	1		13	82
		June 2	5		14	81⅔
		June 3	6	1	15	81¾
		June 4	3	4	16	82
22	May 20	June 2	1		13	81¾
		June 3	4	3	14	81⅔
		June 4	5		15	82
		June 5		6	16	82
		June 7	1	2	18	82
5	May 21	June 4	2		14	82
		June 5	1	2	15	82
3	May 22	June 7	1	1	16	82
		June 10		1	19	82
Total			45	36	1,226	
Average					15.1	81.75

Sometimes there is but one generation, but more often two per year, at Columbia, S. C., according to studies made by R. J. Kewley. He observed that the majority of adults emerged during August, and therefore had ample time to parasitize hosts for another complete generation maturing the following spring. On the other hand, there is strong evidence that in some cases there may be only one generation per year. In the case of a Laphygma larva taken from the field July 26, 1918, an Ophion larva emerged and spun up during the following month. The adult did not issue that fall, and on March 1, 1919, when the cocoon was examined the larva was found to be in good condition, but was accidentally killed. The summer cycle apparently is short, lasting a little over a month, as the following records show. In a cage containing Ophion adults, a reared Laphygma larva was placed on August 10, 1917, and removed the following day. From this host an Ophion larva emerged and spun up August 19, and on September 13 an adult female issued.

At Brownsville, Tex., Vickery observed that this species may remain in the cocoon stage for a considerable length of time. From this host an Ophion larva, which spun a cocoon on May 30, 1912, issued as an adult September 10. This means that 102 days was the period spent within the cocoon.

This species may at times be parthenogenetic, as observed by Kewley. A virgin female was placed in a cage with a reared Laphygma larva on August 11, and the following day the larva was taken out. An Ophion larva emerged therefrom and spun up August 22; the cocoon was opened November 14, and the larva was found to be in good condition. This individual had apparently a yearly cycle. In another cage a virgin female was placed with a reared Laphygma larva on August 14, and the larva was removed the following day. From this larva an Ophion larva emerged and spun up on August 26, 1916, producing a male that issued September 14.

At Brownsville, Tex., the period between oviposition and emergence of adult parasites was approximately 30 days during October and November. The time spent in the cocoon was from 20 to 25 days during the same months and from 25 to 29 days in November and December.

G. G. Ainslie reared an adult of this species on September 2, 1912, from a Laphygma larva collected at Mobile, Ala., on August 16.

Two species of the genus Sagaritis have been reared from Laphygma larvae at various points in the southeastern United States. The species reared are *S. dubitatus* Cresson and *S. oxylus* Cresson. The former species is far more common and appears to have a much wider distribution than the latter.

Sagaritis dubitatus Cresson was first reared from the fall army worm by F. M. Webster, on September 30, 1884. G. G. Ainslie reared it November 25, 1912, at Lakeland, Fla., and the following spring he again reared it at Lakeland and also at Orlando, Fla. He observed that the period spent in the cocoon, in southern Florida, during March, varied from 7 to 10 days.

At Columbia, S. C., Kewley records an average pupal stage of about six days during July, August, and September in a series of eight individuals. The shortest pupal period for any individual in this series was four days, the longest seven days.

The species was reared at Nashville, Tenn., by G. G. Ainslie during late September and early October, 1914. Ainslie observed that the pupal period varied from a minimum of 9 days to a maximum of

11 days. S. E. Crumb reared the species at Clarksville, Tenn., during August and September, 1912, and C. F. Turner reared adults at Greenwood, Miss., during October, 1915.

R. N. Wilson, during June, 1914, reared an adult at Gainesville, Fla., from a fall army worm collected at Lakeland, Fla.

R. A. Vickery reared an adult at Brownsville, Tex., from a consignment of larvae sent him on October 14, 1915, by C. L. Scott, at that time connected with the Federal laboratory at Wellington, Kans. Vickery also reared adults from fall army worms collected at Brownsville, Tex. He observed a cocoon period of from 7 to 8 days in April, 5 to 6 days in May, and further observed that the time between oviposition and emergence of the adults was 13 days during May and June.

Parasitic larvae of this species emerge from their hosts when the latter are in the fourth instar. The host larvae are retarded in their development by the action of this parasite. The parasitic larva upon emergence constructs its cocoon on a blade of grass, corn leaf, piece of wood, or other object that lies close to it.

Observations on the construction of the cocoon were made by R. A. Vickery at Brownsville, Tex., and in part are as follows:

> The infested Laphygma larva remains attached to the plant by its prolegs and the parasitic larva with its head towards the caudal end of the caterpillar cuts its way out on the ventral side, cephalad of the prolegs, crawls out part way, swings back its anal end so as to fold back the host larval skin on itself. As the parasitic larva crawls forward, the host larval skin is partly carried with it and remains stretched out and flattended on the plant. Some larvae begin to spin their cocoons when half way out, while others crawl a few millimeters before spinning. The parasitic larva starts its cocoon by attaching threads to the plant and then to its back, repeating this process on the other side, attaching the threads to the plant and then to the threads already spun, thus forming a loop over itself. This loop becomes the rear end of the cocoon. The larva works forward with its ventral side up. It reaches forward to one side and attaches a thread to the plant. It then brings its head back, spinning a thread which it loops several times and attaches it at several places, finally bringing this thread forward and attaching it to the plant on the other side. The larva repeats this process until it reaches the front end of the cocoon, when it attaches the ends of several threads to the plant on each side. The larva then fills in this end of the cocoon by looping threads back and forth across it and spins threads back and forth on this frame-work to strengthen it, reversing itself so that it can get at all parts of the cocoon. The framework is all made up of a single thread, probably formed by the union of two threads, one from each spinneret. It requires about three-fourths of an hour to complete the framework. After making the framework the larva rapidly lines it by spinning two parallel threads which run in every direction crossing and recrossing each other until the cocoon is lined with a continuous layer of silk. In about two hours the work is so far complete that further observation is no longer possible.

The cocoon is attached to the plant only by the ends of the threads which are attached when the cocoon is being started. It is brownish in appearance and measures 5.2 mm. in length and 1.9 mm. in width.

The host larvae are stung just before they emerge from the eggs. As many as 14 host larvae have been stung by one female in 13 minutes; it requires only about two seconds for a female to deposit an egg.

Adults of *Sagaritis oxylus* Cresson issued from Laphygma larvae at Nashville, Tenn., on September 11 and September 15, 1915, from material under observation by W. B. Cartwright. The determination of the parasite was made by A. B. Gahan, of the United States Bureau of Entomology.

Neopristomerus appalachianus Viereck was reared from Laphygma larvae at Brownsville, Tex., but is not a common parasite in that region. It may be considered as one of the rarest of the parasitic Hymenoptera parasitizing the fall army worm, as seldom more than a few specimens were reared from collections of Laphygma larvae made in the field at that place. The rate of infestation ranged from 1 to 2 per cent of the number collected. Furthermore, this species was obtained only when collections of young larvae were made, which would seem to show that only young Laphygma larvae are parasitized by it and that the parasitic larvae leave their hosts before the latter are mature. The period spent in the cocoon by this parasite in April was observed to be 14 days, at an average mean temperature of 74° F.

From a fall army worm collected at Winfield, Kans., on September 25, 1914, by T. S. Wilson and taken to the laboratory at Wellington, Kans., to rear, a large hymenopterous parasite, *Paniscus geminatus* Say, had issued and pupated on October 20. On December 15 an adult issued, which was determined by A. B. Gahan, as was the above species.

One specimen of *Enicospilus purgatus* Say was reared from a fall army worm at Columbia, S. C., during July, 1913. This parasitic larva issued from the prepupa of the host.

Enicospilus concolor Cresson is mentioned by Wilson (*66, p. 5*) as an enemy of the fall army worm in St. Croix, Virgin Islands.

Adults of a species of Ichneumonidae recorded in the notes on file in the Bureau of Entomology as Pimpla sp. were reared by Harry Pinkus from Laphygma larvae collected at Opelousas and Nacogdoches, Tex. J. L. Webb also reared an adult in the same year from a larva taken at Crowley, La.

BRACONIDAE

Chelonus texanus Cresson (fig. 39), an important parasite of Laphygma larvae, has a most remarkable and interesting life history. The female oviposits in the eggs of the host, but instead of the parasites emerging from the eggs they emerge from the immature larvae.

This parasite has been taken at different times in Arkansas, Louisiana, Mississippi, and Texas. It was a subject of special study by McConnell, Parks, and Turner from 1912 to 1915. These men have contributed largely to the knowledge of the life history of the insect. Pierce and Holloway (*41*), and other men of the Division of Southern Field Crop Insects, have made notes on it.

In Texas the species is found throughout the year, but in the region of Greenwood, Miss., it has never been taken before August and has not been found in abundance at that place until September. Numbers of specimens have also been taken during October.

As mentioned above, the eggs of the host are stung. Such parasitized eggs show no signs of abnormal development but hatch in the same length of time as unparasitized ones.

Larvae hatching from eggs parasitized by Chelonus develop normally at first, but are gradually retarded in their development and spin a premature cocoon, which is known by some writers as the "death cell." Host larvae that are parasitized reach a length of about one-half inch, look emaciated, and have a rough, dry skin. When dissected such larvae are seen to have lost most of the body juices. Chelonus larvae emerge from Laphygma larvae in from 12 to 14 days after the eggs of the moth hatch.

When a female of Chelonus is placed in a vial containing an egg mass of Laphygma she may begin to oviposit immediately. She approaches the eggs cautiously and places the tips of the antennae on an egg, the antennae vibrating vigorously all the time. She takes a position over the egg, and the ovipositor is raised and lowered a few times until the body is properly adjusted. Then the ovipositor is pushed down into the egg and retained there for a

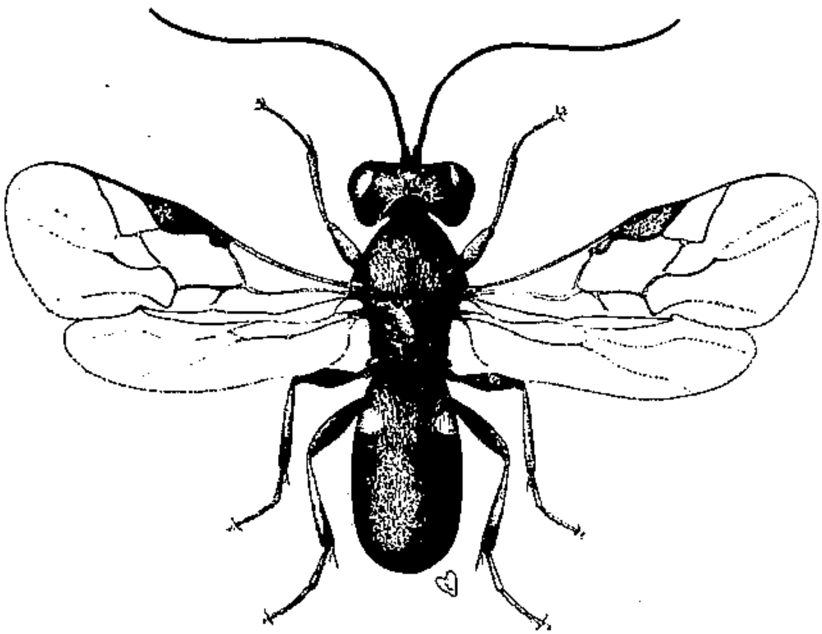

FIG. 39.—*Chelonus texanus*, a parasite of the fall army worm. Greatly enlarged. (Walton and Luginbill)

period of a few seconds to one-half minute or more. In 35 minutes, at a temperature of 72° F., one female oviposited thirteen times. Another individual oviposited eight times in one minute, and subsequently in a like period of time oviposited five times. On two other occasions the act of oviposition required about five seconds. Some of the eggs are stung twice, while others are stung three times.

The larva of Chelonus (fig. 40, A) usually is whitish in color but sometimes may show pinkish markings. Upon emergence from a host larva, not contained in a cell, the parasite takes from two to four days to complete a cocoon. When in the so-called "death cell" of the host the larva undoubtedly constructs its cocoon in a much shorter period, as cocoon construction is then more easily accomplished.

The emergence hole through which the parasitic larva leaves its host usually is on the ventral side of the abdomen.

The parasite passes the winter in the cocoon, apparently as a pupa. (Fig. 40, B.)

The cocoon (fig. 40, C, D) is a beautiful structure, made of thin-meshed white silk, and usually it is made within the "death cell." It has been observed that when the host larva does not spin a "death cell," or is prevented from doing so, the parasitic larva when it

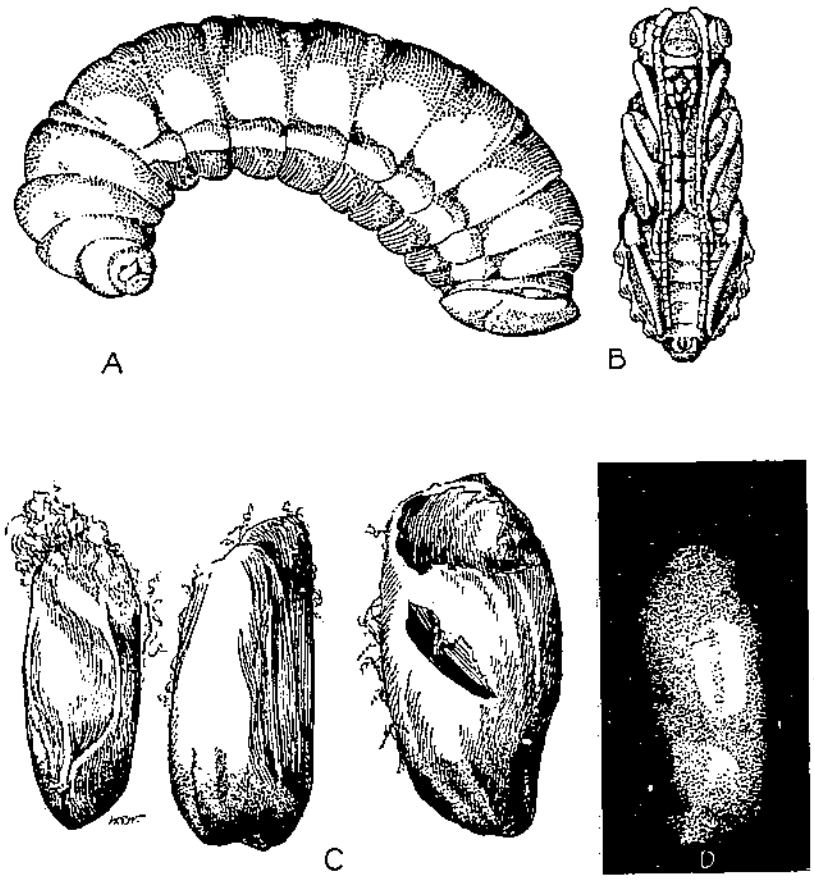

FIG. 40.—*Chelonus texanus:* A, larva; B, pupa; C, empty cocoons; D, cocoon. All much enlarged

emerges usually dies, having no foundation upon which to spin its cocoon. If the parasitic larva does pupate under such conditions it invariably dies.

Chelonus adults feed at the nectaries of cotton and other plants and may be taken from these plants while feeding. When busy ovipositing they may be taken readily with the egg mass and placed in a vial without disturbing them in the least.

This is probably one of the most important parasites of the fall army worm in the States where it occurs. Indeed it would seem that outbreaks of Laphygma in the Southern States depend to a large extent on the scarcity of this species. Whenever collections of young larvae were made in Texas this species was observed to be the dominant parasite. The following observations illustrate this fact: From a collection of 500 larvae of various sizes made at San Benito, Tex., by T. S. Wilson, 254, or about 51 per cent of the number, were parasitized with Chelonus, and in another instance 70 per cent of a collection of 200 larvae were infested with this species. In the majority of cases the percentage of infestation ranged between 25 and 50 per cent of the number of host larvae collected. In southern Texas this insect is most abundant during the period from June to September, inclusive.

This species has also been abundant in some years during late summer in Mississippi. Of 366 Laphygma larvae collected at Greenwood, Miss., by McConnell and his assistants during August and September, 1915, 36.2 per cent were parasitized by Chelonus.

The time intervening between oviposition and emergence of the adult at Greenwood, as recorded by McConnell, is shown in Table 17. The table shows that this period varied from a minimum of 32 days to a maximum of 69 days, the average length of the period for the five individuals being 60.4 days. At Brownsville, Tex., this period has been determined as 20 days in June, 18 to 21 in July, 23 to 26 in August and September, and 27 days in October. The time spent in the cocoon at Brownsville was about 8 days in June, when the average mean temperature was 79½° F.

Adults issuing late in the season, as shown in Table 17, probably die without reproducing, because Laphygma eggs are not available then. However, it is possible that the species has hosts other than Laphygma and Chloridea in which it may breed. A number of Chelonus larvae that pupated at about the same time as those mentioned in Table 16 overwintered in the cocoon, and it is quite possible that this insect winters only in the cocoon stage.

TABLE 17.—*Time intervening between oviposition and emergence of adult of Chelonus texanus, at Greenwood, Miss., 1913*

Date of oviposition	Date larva emerged	Date larva finished cocoon	Date adult issued	Period (days)
Sept. 23	Oct. 11	Oct. 13	Nov. 29	67
Sept. 24	Oct. 12	Oct. 15	Dec. 2	69
Do	Oct. 10	Oct. 11	Oct. 26	32
Sept. 25	Oct. 11	Oct. 13	Dec. 2	68
Sept. 27	Oct. 13	Oct. 16	do	66
Average				60.4

Apanteles marginiventris Cresson (Synonyms: *A. grenadensis* Ashm., *A.* (*Protapanteles*) *harnedi* Vier., and *A. laphygmae* Ashm. Ms. Chittn.) was reared in abundance from Laphygma larvae by S. E. Crumb at Clarksville, Tenn., in 1912, and by G. D. Smith at Tallulah, La., during July of the same year. Chittenden mentions that an adult of this species was reared August 29–30 from armyworm material received from Savannah, Ga.

At Brownsville, Tex., Vickery observed that the period between oviposition and the emergence of the adult was 14 days in November and from 10 to 14 days during June. The time spent in the cocoon stage was 14 days in January, 7.5 days in April, and only three days in June. The length of this stage in October and November, from records obtained by R. A. Vickery, is given in Table 18, which is based on 50 individuals, of which 47 are males and only 3 females. The average time spent in the cocoon was 6.68 days, the average mean temperature of the period being 69.9° F.

TABLE 18.—*Length of the cocoon stage of Apanteles marginiventris, at Brownsville, Tex.*

Number of individuals	Cocoons spun	Date adults emerged	Number of—		Length of stage (days)	Average mean temperature °F.
			Males	Females		
2	Oct. 24	Oct. 30	2		6	69.5
5	do	Oct. 31	5		7	70
1	do	Nov. 1	1		8	70.3
1	Oct. 25	Oct. 30	1		5	69
12	do	Oct. 31	12		6	69
3	do	Nov. 1	3		7	70
2	do	Nov. 2	2		8	70
3	Oct. 26	Nov. 1	3		6	70
5	do	Nov. 2	5		7	70
3	do	Nov. 3	1	2	8	70.3
1	do	Nov. 4	1		9	70.5
2	do	Nov. 5	1	1	10	70.6
1	Oct. 27	Oct. 31	1		4	69
8	do	Nov. 2	8		6	70.3
1	do	Nov. 3	1		7	70.5
Total			47	3		
Average					6.68	69.9

At Columbia, S. C., Kewley observed that the length of the cocoon stage during July and August in a series of three individuals was from four to seven days, with an average of 5.6 days. He also reared this species at College Park, Md., in October, 1915.

The following are other rearing records: Wellington, Kans., T. S. Wilson, August 31, 1914; Orlando, Fla., G. G. Ainslie, February 4, 1913; Hunneville, Kans., T. S. Wilson, August, 1915; Greenwood, Miss., J. M. Langston, July 17, 1915.

This Apanteles oviposits readily in the first instar of Laphygma larvae. It thrusts the ovipositor in and withdraws it almost immediately, passing over the host larva almost without stopping. Apanteles larvae usually emerge from fourth-instar host larvae. Occasionally, however, they emerge from older larvae.

This species may breed parthenogenetically, in which case the offspring are all males. From one virgin female a progeny of 45 adults were obtained. This species is widely distributed in the Southern States and appears to be indigenous to that region. However, it is not one of the most common of the parasites of Laphygma larvae, as the percentage parasitized in collected Laphygma larvae seldom exceeded 10. In a few cases parasitism in such material reached as high as 30 per cent.

Hosts other than *Laphygma frugiperda* are *Plathypena scabra* Fab., *Cirphis unipuncta* Haw., *C. latiuscula* Herrich-Schaeffer (Vickery), *C. multilinea* Walk. (Vickery), *Laphygma exigua* Hübn., *Heliothis obsoleta* Fab., *Prodenia eridania* Cramer, and species of Autographa.

Three species of Meteorus have been reared from *Laphygma frugiperda* larvae, namely, *M. autographae* Mues., *M. laphygmae* Vier., and *M. vulgaris* Cresson.

Two adults of *Meteorus autographae* Mues. were reared from fall army worms at Nashville, Tenn., by G. G. Ainslie in October, 1914; they had a cocoon period of nine days. One of the hosts from which a parasite emerged lived for one day after the parasite left it.

R. J. Kewley bred this parasite from Laphygma larvae during the year 1916 at Columbia, S. C., and made a thorough study of the life history and habits of the species. He again reared this parasite at Columbia, S. C., in 1920.

According to Muesebeck (*39, p. 30, 31*), hosts other than *Laphygma frugiperda* are *Autographa brassicae* Riley, *Cirphis unipuncta* Haw., *Plathypena scabra* Fab., *Phlyctaenia ferrugalis* Hübn., *Eurymus eurytheme* Bois., *Prodenia eridania* Cramer, *Evergestis straminalis* Hübn., *Alsophila pometaria* Harris, and *Autographa* sp., possibly *verruca* Fab. (McConnell).

Meteorus laphygmae Vier. is a common and important parasite of Laphygma larvae in southern Texas. As high as 40 per cent of a collection of larvae has been found parasitized by this species. Usually, however, parasitism does not exceed 20 per cent, and a percentage of from 10 to 15 is more common.

The period between oviposition and the emergence of adults at Brownsville, Tex., has been determined by Vickery to be as follows: 14 to 18 days in May and June at an average mean temperature of 79° F.; 12 days in July at an average mean temperature of 83°; 20 to 24 days in October at an average mean temperature of 70°; from 21 to 26 days in October and November at an average mean temperature of 70°. The time spent in the cocoon is 6 to 7 days in May, 5 days in June and July, 6 to 8 days in October, and 8 to 9 days in October and November.

An adult of this parasite was reared at Nashville, Tenn., September 1, 1915, by W. B. Cartwright.

The host larvae usually are stung when in the second or third instar, and these stages seem to be preferred. However, females have been observed to oviposit in first-instar larvae, but in such cases the development of the parasite required several days longer than when the host larvae were stung later in life.

Laphygma larvae parasitized by this species were retarded in development.

This parasite may reproduce parthenogenetically, and the resulting progeny are always males. An unmated female was placed in a cage with a number of Laphygma larvae in the second and third instars and left for a few days. Ten days later a number of parasitic larvae emerged and pupated. At the time of emergence the host larvae were in the fourth and fifth instars. Adult parasites issued from 10 to 11 days later, making the period between oviposition and the emergence of adults approximately 20 to 21 days.

This parasite itself is subject to parasitism, as a number of different hyperparasites have been reared from it. From a Meteorus cocoon collected at Brownsville, Tex., in July, 1912, an adult of *Dibrachys meteori* Gahan and one of *Spilochalcis torvina* Cresson issued.

According to Muesebeck (*39, p. 32, 33*), other hosts of this parasite are as follows: *Lycophotia margaritosa* Haw., *Laphygma exigua* Hübn., *Feltia annexa* Treitschke, *Heliothis obsoleta* Fab., Prodenia species, Monodes species, *Eurymus eurytheme* Bois.

According to Muesebeck (*39, p. 31, 32*), *Laphygma frugiperda* is a host of *Meteorus vulgaris* Cresson.

Two species of Rogas have been reared from fall army worms, namely, *R. terminalis* Cresson and *R. laphgymae* Viereck, neither of which appears to be very common.

There seems to be but one record of *R. terminalis* Cresson from the fall army worm. This was made by W. B. Cartwright at Nashville, Tenn., in 1915; the determination was made by A. B. Gahan.

Rogas laphygmae Viereck was reared from Laphygma at Brownsville, Tex. It was observed that the females prefer to parasitize host larvae which are about ready to pass into the second instar. The parasitic larva emerges from its host when the latter is in the fourth instar. Parasitism by this species retards the development of the host. Among a single brood of larvae it was observed that when parasitic larvae emerged the host larvae were in the fourth instar while the unparasitized Laphygma larvae were in the fifth instar. The period between oviposition and emergence of adults at Brownsville was 10 to 14 days in June and July. The time spent in the cocoon was from three to five days during the same months.

Parthenogenesis occurred in this species, the resulting progeny being a male. An unmated female was placed with a first-instar Laphygma larva and left 24 hours. A parasitic larva emerged and spun up in nine days, and the adult appeared five days later.

When the parasitic larva is mature it fills the body of the host, which dies and remains attached by the prolegs to the plant. The Rogas larva proceeds to clean out the head and thorax of the host and then works on its ventral side until only the epidermis is left. It soon breaks through and ejects juices and material not needed. The drying of this material attaches the host to the plant. The skin of the host over the region of the thorax and over the last prolegs collapses, and between these collapsed portions the parasite spins its oval cocoon. The host larval skin, being freed from all soft material, soon dries, hardens, and forms a strong protection for the cocoon.

T. D. Urbahns reared an adult of *Zele melleus* Cresson September 11, 1912, at Chillicothe, Tex. Adults were also reared by G. G. Ainslie from the same host at Nashville, Tenn., in 1914 and 1915; by R. A. Vickery at Brownsville, Tex., in October, 1913, and again in October, 1914.

R. J. Kewley reared this parasite at Columbia, S. C., during July and August, 1917; in August, 1919; and in 1920 reared a number of the adults during the period between August 29 and October 13. The length of the period spent in the cocoon varied from 8 to 16 days, with an average of 11.8+ days for 6 individuals. The adults lived for a period varying from 7 to 25 days, with an average of 13.8+ days in a series of 5 individuals.

The cocoon of this parasite when just formed is white with shining pale brown at the caudal end. Later it changes to pale brown with a white band around the middle.

CHALCIDOIDEA

Trichogramma minutum Riley (*T. minutissimum* Pack., *T. pretiosum* Riley), a minute egg parasite, was reared from Laphygma eggs at Greenwood, Miss., by McConnell and Parks in 1912. On October 15 of that year McConnell found an egg mass of Laphygma on corn, all the eggs in the mass being much wrinkled and black in color. From these eggs Trichogramma adults issued on October 18.

Several attempts were made to breed this species into Laphygma eggs in cages, only one of which was successful. The female, upon finding an egg mass, inspects it very closely and races around it until an egg is found that is well exposed and free from covering of scales. The parasite appears to be very much bothered by the scales which usually cover the egg masses of Laphygma, and doubtless this is the reason why Trichogramma has not more often been reared from Laphygma eggs. In oviposition the adult takes a position over the host egg and places the tip of abdomen down upon it, remaining

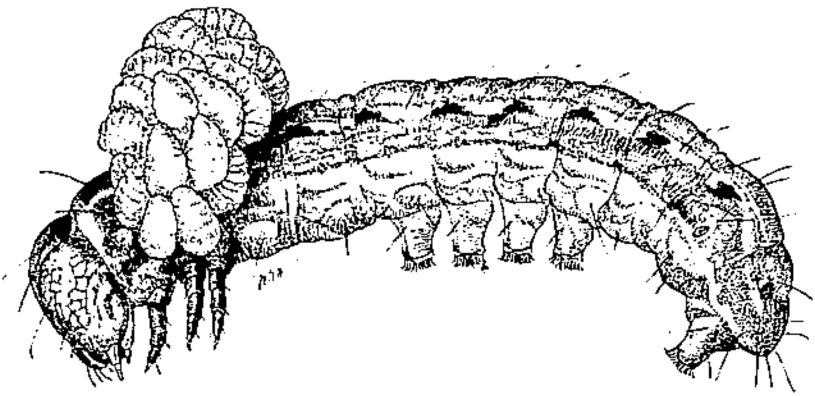

FIG. 41.—A colony of Euplectrus larvae feeding on a fall army worm

thus for several seconds, during which interval the egg is inserted within the host.

From eggs that were parasitized on October 18, adults began to emerge on October 31, and others issued from November 9 to 10.

This species is a common parasite of *Diatraea saccharalis* Fab., according to Holloway, and is also known as a parasite of *Heliothis obsoleta* Fab.

Two species belonging to the genus Euplectrus have been reared from Laphygma larvae, namely, *E. comstockii* How. and *platyhypenae* How. Both have a wide distribution in the South and have been reared from larvae of other species of Lepidoptera.

The parasites belonging to this genus have a most interesting life history. The eggs are placed externally on the dorsum of the caterpillar, usually in the region of the thorax, and the larvae hatching out begin to feed in this external position. When the parasitic larvae are about mature they give the host a humped appearance to the unaided eye, due to the larvae being grouped very closely together. Figure 42 shows a group of Euplectrus larvae about mature but still feeding.

G. G. Ainslie, while stationed at Orlando, Fla., reared adults of *Euplectrus comstockii* Howard, February 20, 1913. The period spent in the cocoon was 8 days. T. S. Wilson reared adults of the same species at Wellington, Kans., in October, 1914. He observed a cocoon period of from 15 to 38 days.

Chittenden records the rearing of 25 adults from a single host larva.

This species of Euplectrus is also an enemy of *Alabama argillacea* Hübn.

Euplectrus platyhypenae Howard (fig. 42) has been reared repeatedly at Brownsville, Tex., though it is not to be considered as abundant in that region. In May the egg stage was from 2½ to 3 days in length, the larval stage from 3 to 4 days, and the pupal stage, or the time spent in the cocoon, from 6 to 7 days. In November

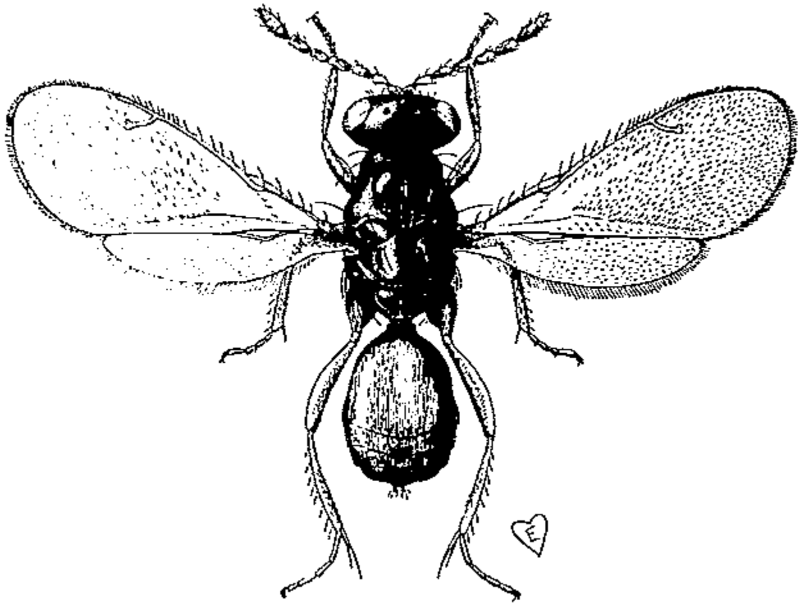

FIG. 42.—Adult of *Euplectrus platyhypenae*. Greatly enlarged

these stages had a minimum length of 6 days for the egg stage, 5 days for the larval stage and 7 days for the pupal stage.

E. G. Smyth, at Brownsville, Tex., reared 167 adults from 6 host larvae, 80 per cent of the adults being females. On other occasions he made the following rearings: 90 Euplectrus larvae and pupae from 6 host larvae, the greatest number of larvae on one host being 31, the smallest 3; 31 *E. platyhypenae* larvae from another host, from which developed 25 females and 1 male; from another individual were reared 15 males and 10 females; from another, 27 females and 3 males; from another, 37 females and 8 males. This would seem to show that there is a preponderance of females in this species.

Adults of this parasite may live for a considerable length of time in confinement when given food. Vickery observed that one male lived 97 days in a room the temperature of which was about 70° F.

This species may sometimes reproduce parthenogenetically. An unmated female was placed in a vial with a Laphygma larva. The following night 28 eggs were deposited on the larva. The eggs hatched in 3 days, and the larvae matured in 4 days, while the time spent in the cocoon was 6 days. The adults were males.

This species has also been reared from specimens of fall army worms taken at Texarkana, Ark., and Greenwood, Miss. Kewley reared it at Columbia, S. C., during the summer season of 1917 and made quite an extensive study of its habits and life history.

(*Chalcis*) *Brachymeris robusta* Cresson, *Spilochalcis femorata* Fabricius, and *S. vittata* Ashmead are mentioned by Wilson (*66, p. 5*) as enemies of the fall army worm in St. Croix, Virgin Islands.

HYPERPARASITES

In his studies of the parasites of Laphygma, at Brownsville, Tex., R. A. Vickery observed and reared quite a number of secondary para-

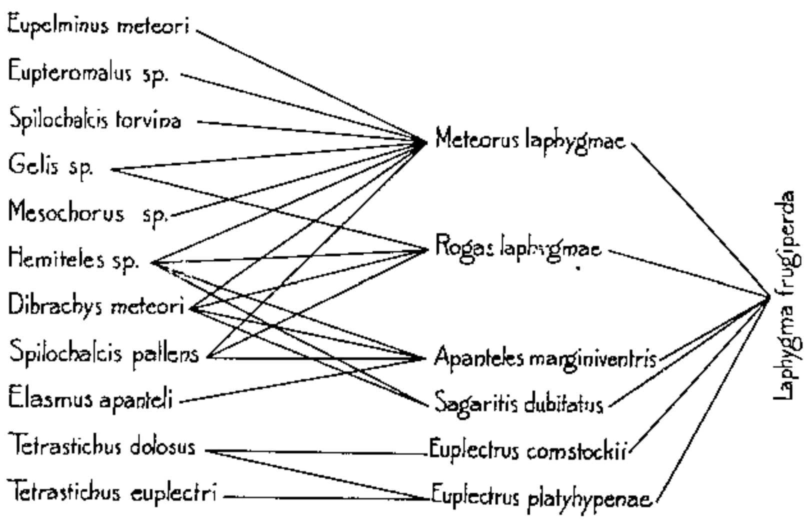

FIG. 43.—Diagram showing relationship between *Laphygma frugiperda* and some of its parasites and hyperparasites (Hymenoptera)

sites or hyperparasites. (Fig. 43.) He was able to breed a number of different species and thus to obtain data on their habits and life cycles. It is to be understood that the following information on these parasites has been taken largely from the notes made by Vickery, unless otherwise stated.

ICHNEUMONIDAE

Adults of an unidentified species of Hemiteles were reared in June, 1914, from cocoons of *Apanteles marginiventris; Rogas laphygmae*, *Sagaritis dubitatus*, and *Meteorus laphygmae*, collected in the field.

Oviposition was observed in a rearing cage containing some Sagaritis cocoons and a female Hemiteles. The female had no difficulty in penetrating the cocoon with its ovipositor. She first examined the cocoon very carefully, facing one way, then another. She then mounted the cocoon and bent her abdomen forward under her body and placed the point of the ovipositor in contact with the cocoon. Then slipping the ovipositor out of its sheath, she brought her abdomen back to its normal position, the ovipositor being left under the center of the abdomen, pointing downward. She next pushed the ovipositor into the cocoon until the tip of the abdomen was in contact with the cocoon. Then, resting on the tip of the abdomen and using it as a fulcrum, she partly withdrew her ovipositor and pressed it back in again until the desired spot was reached.

The period between oviposition and the emergence of adult has been determined as 9 to 10 days in July, at an average mean temperature of 83° F. This species is sometimes parthenogenetic, the resulting progeny being males.

An adult belonging to the genus Gelis was reared from a cocoon of *Rogas laphygmae* collected in July, 1912, at Brownsville, Tex. It was again reared from a collection of 295 *Meteorus laphygmae* cocoons collected by E. G. Smyth in July and August at the same place. Ten individuals were reared from this lot. Smythe observed the female Gelis ovipositing in a Meteorus cocoon which was suspended from a blade of Bermuda grass by a silk thread. It took the female 17 minutes to oviposit, several incisions being made during this time.

An adult of a species of Mesochorus was reared January 28, 1913, at Orlando, Fla., by G. G. Ainslie. Two adults, apparently of this same species, were reared at Greenwood, Miss., by J. M. Langston in 1915. Langston records a cocoon stage of 8 to 14 days. At Brownsville, Tex., three individuals were rearerd from a lot of 295 *Meteorus laphygmae* cocoons collected by Smyth. The scarcity of this hyperparasite shows its apparent insignificance as an enemy of Meteorus.

CHALCIDOIDEA

A cocoon of *Meteorus laphygmae*, collected in the field on May 28, 1914, yielded a female of *Eupelminus meteori* Gahan on June 23. This female was at once placed in a vial with five reared Meteorus cocoons. The cocoons were opened some days later, and in one of them a parasite of the above species was found.

E. G. Smyth, at Brownsville, Tex., reared a number of adults of this species from a field collection of 295 Meteorus cocoons.

A number of adults of *Dibrachys meteori* Gahan were reared in June, 1914, from cocoons of *Rogas laphygmae*, *Sagaritis dubitatus*, and *Meteorus laphygmae* collected in the field.

In rearing cages in which adults were confined with hosts the period between oviposition and emergence of adults in June was as follows: With *Sagaritis dubitatus* as a host, 10 days at an average mean temperature of 82° F.; with *Meteorus laphygmae* as a host, also 10 days at an average mean temperature of 83° F.; with *Rogas laphygmae* as a host, 11 days, the adult in this case being a female. The length of the life cycle appears to be about the same irrespective of the host species.

On one occasion it was possible to observe the development of a Dibrachys larva by transmitted light under the binocular microscope. The larval stage was determined as about four days.

Smyth reared 29 adults in July and August, 1912, from a collection of 295 *Meteorus laphygmae* cocoons collected in the field at Brownsville, Tex.

Adults of this species were also reared from cocoons of *Apanteles marginiventris*.

In making observations on the deposition of eggs by Dibrachys it was observed that about one hour is required for the operation. The parasite closes the hole made by the ovipositor in the cocoon after the egg is placed. The spot selected for the deposition of the egg is at the cap end, which places the egg near the thorax of the host. One female, when disturbed while ovipositing, returned later and sought the hole she had originally started and completed the operation of oviposition.

According to A. B. Gahan (*18*), this parasite occurs also at Memphis, Tenn.

Adults of *Spilochalcis pallens* Cresson were reared from cocoons of *Rogas laphygmae* collected in the field in July, 1914, and from cocoons of *Meteorus laphygmae* collected in the field in September of the same year.

E. G. Smyth reared 69 adults of *S. pallens* from a collection of 295 *Meteorus laphygmae* cocoons made at Brownsville, Tex., in August, 1912. This shows a percentage of infestation of about 30 for this parasite and reduces somewhat the efficiency of the Meteorus parasite as an enemy of the fall army worm.

The species was also reared at Columbia, S. C., on October 10, 1916, by R. J. Kewley.

A reared female *S. pallens* was placed in a vial with cocoons of *Apanteles marginiventris*. She was observed to oviposit, the operation requiring about 10 minutes. This individual had no difficulty in penetrating the Apanteles cocoon. On the other hand, ovipositing in Meteorus cocoons required about three-fourths of an hour.

Adults of this hyperparasite have been kept alive for a period of 60 days. During this time they were fed and kept in a room the temperature of which averaged about 70° F.

The time required for the development of the parasite from oviposition to emergence, using *Apanteles marginiventris* as a host, was 13 days in October, at an average temperature of 76° F., 31 days in October and November, at an average mean temperature of 67°. The time required for this period when *Meteorus laphygmae* was used as a host was 15 days in October. The pupal stage in the latter case was 9 days, the average mean temperature of the period being 73.5°.

Table 19 shows the results obtained with *S. pallens*, using *Meteorus laphygmae* as a host, in determining the life cycle. These progeny were all males, 24 in number. The length of the egg and larval stage varied from 7 to 9 days and the pupal stage from 6 to 9 days, while the total life cycle was from 14 to 24 days, with average mean temperatures varying from 68° to 76.5° F.

TABLE 19.—*Life-cycle experiments with Spilochalcis pallens, using Meteorus laphygmae as a host, at Brownsville, Tex., 1914*

Date parasites were placed with cocoons	Date parasites were removed	Date Spilochalcis larvae pupated	Length of egg and larval stage	Average temperature	Date adults emerged (males)	Length of pupal stage	Average temperature	Total life cycle	Average temperature
			Days	*°F.*		*Days*	*°F.*	*Days*	*°F.*
Oct. 5	Oct. 6	Oct. 12	7	80	Oct. 19, 1	7	73	14	76
Do	do	do	7	80	Oct. 21, 1	9	73.5	16	76.5
Oct. 8	Oct. 9	Oct. 16	7	75.5	Oct. 24, 2	8	76	15	76
Oct. 9	Oct. 10	Oct. 18	8	76	Oct. 24, 1	6	78	14	76
Do	do	do	8	75	Oct. 25, 2	7	77	15	76
Do	do	Oct. 19	9	75.5	do	6	76	15	76
Do	do	do	9	75.5	Oct. 27, 2	8	75	17	75
Oct. 11	Oct. 12	do	7	74	Oct. 27, 1	8	75	15	74
Do	do	Oct. 20	8	75	do	7	74	15	74
Do	do	do	8	75	Oct. 28, 1	8	73	16	74
Do	do	Oct. 21	9	76	Oct. 29, 1	8	72	17	73.5
Do	do	do	9	75	Oct. 30, 2	9	72	18	73
Do	do	Oct. 20	8	75	Oct. 28, 1	8	73	16	74
Do	do	do	8	76	Oct. 29, 1	9	73	17	73.5
Nov. 2	Nov. 2				Nov. 28, 3			24	68

Adults of the hyperparasite *Spilochalcis torvina* Cresson (*S. delira* (Cress.) Viereck) were reared from *Meteorus laphygmae* cocoons collected in September, 1914. An experiment was conducted with *S. torvina*, using *Meteorus laphygmae* as a host, and the results obtained are given in Table 20. This table shows that the period between oviposition and the emergence of adults at that time of the year varied from 17 to 27 days at an average mean temperature varying from 66° to 73.5° F.

TABLE 20.—*Life-cycle experiments with Spilochalcis torvina, using Meteorus laphygmae as a host, at Brownsville, Tex., 1914*

Date parasites were placed with cocoons	Date parasites were removed	Date Spilochalcis larvae pupated	Length of egg and larval stage	Average temperature	Date adults emerged (males)	Length of pupal stage	Average temperature	Total life cycle	Average temperature
			Days	*° F.*		*Days*	*° F.*	*Days*	*° F.*
Oct. 11	Oct. 12	Oct. 20	8	75	Oct. 29, 2	9	72	17	73.5
Oct. 18	Oct. 19	do			Nov. 6, 1			18	73
Do	do				Nov. 7, 1			19	73
Nov.	Nov. 10	Nov. 17			Dec. 7, 2	20		27	66

Of 295 *M. laphygmae* cocoons collected at Brownsville, Tex., in July and August, 1912, by E. G. Smyth, 38, or 16 per cent of the number, were parasitized by this species.

Attempts were made to cross *S. pallens* and *S. torvina*. There was courtship but no mating.

According to A. B. Gahan (*20, p. 215*), the hyperparasite *Tetrastichus dolosus* Gahan has been reared by R. A. Vickery at Tallulah, La., from *Euplectrus platyhypenae* parasitizing *Laphygma frugiperda*, and by T. S. Wilson at Wellington, Kans., from *E. comstockii* parasitizing *Caradrina* sp.

A. B. Gahan (*19, p. 167*) records *Tetrastichus euplectri* as having been reared from *E. platyhypenae* by R. A. Vickery. The host was collected at Tallulah, La.

Elasmus apanteli Gahan is recorded by A. B. Gahan (*18, p. 438*) as having been reared at Memphis, Tenn., by W. R. McConnell from a cocoon of *Apanteles marginiventris* parasitizing *L. frugiperda*.

An adult belonging to the genus Eupteromalus was reared from a cocoon of *Meteorus laphygmae* collected in June at Brownsville, Tex.

DIPTEROUS PARASITES

TACHINIDAE

Tachinid parasites play an important part in the control of the fall army worm. In fact, the natural control of outbreaks seems to depend largely upon the abundance of these parasites. During the severe outbreak of 1912, tachinid parasites were scarce at Columbia, S. C., during early summer and did not become abundant until late summer. In Florida, according to G. G. Ainslie, they began to be abundant in July. In the following year (1913) parasitic flies were abundant in a colony of Laphygma larvae on millet and soon were in complete control of the caterpillars.

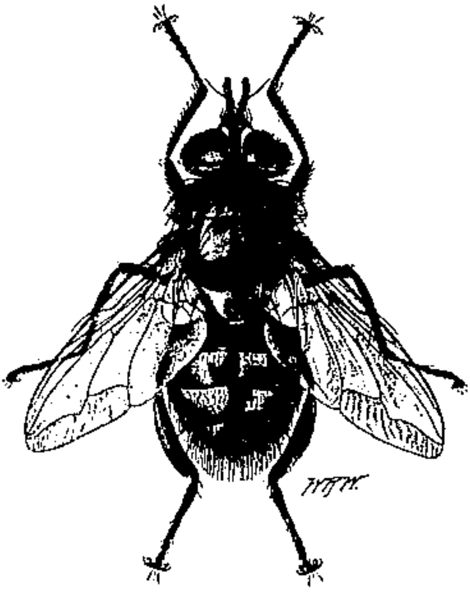

FIG. 44.—Adult of *Winthemia quadripustulata*, a dipterous parasite of the fall army worm. Much enlarged. (Walton)

It is unfortunate that tachinid parasites do not attack the host until the latter is nearly mature and thus has accomplished its most destructive work. In spite of this fact, these parasites of the fall army worm function efficiently by destroying large numbers of a given generation of larvae and thus greatly reducing the succeeding generation.

A number of different species of Tachinidae attack this insect, and the most important of these is *Winthemia quadripustulata*.

The tachinid *Winthemia quadripustulata* Fab. (fig. 44) has a very wide distribution; it occurs throughout the territory invaded by the fall army worm and has been reared from this host in various parts of the country. It is not only an enemy of this army worm but also of the true army worm and many other lepidopterous caterpillars. This fly oviposits on larvae of the fifth and sixth instars. Eggs are placed usually on the dorsum of the thoracic segments of the host. However, they are often found on other parts of the body, sometimes on the head or on the lateral sides of the last abdominal segment. The number of eggs placed on one larva varies greatly, usually being one or two, sometimes three, and when the flies are abundant it is not uncommon to find larvae having as many as six eggs. In one instance 12 eggs were found scattered over the body of one individual. Two or three flies have been reared from one host at Columbia, but not more than three. Walton (*64*) also records the rearing of from one to three flies from a single caterpillar. At Columbia, S. C., in a cage containing a collection of 17 larvae bearing eggs, 24 puparia were taken from the soil. This fly never deposits eggs on very young caterpillars, but always on nearly mature larvae. This seems to be a wise provision of nature to insure the parasite a better chance of life. If the eggs were placed on young larvae, these might molt before the eggs had a chance to hatch, as they would be cast off with the old skin. In a series of 12 nearly mature specimens introduced into a cage with a number of these flies in July, 1914, parasites were reared from only one caterpillar. The five eggs on this specimen were deposited July 10, and three maggots emerged and pupated on the 27th; three adults issued on August 10. The length of the period between oviposition and emergence of adult was 31 days. The remainder of the larvae had from one to seven eggs on their backs but failed to produce flies.

The tachinid larva emerges from the side of the egg next to the caterpillar, and bores directly through the body wall of the host, which is active during most of the time that the maggot is feeding, but dies before the parasite emerges. In some instances maggots do not issue from the host until a day or two after the latter has died. The host seldom burrows into the ground when parasitized, but usually dies on the surface of the ground, and the maggots, after emerging, burrow into the ground to pupate.

In several instances it was observed that the caterpillars pupated even when parasitized and cast the final molt except a small part to which the egg was attached. These pupae acted normally at first. The eggs of the parasite hatched, and the maggots emerged from the pupal cases of the host to pupate.

In August, 1920, *W. quadripustulata* was very abundant at Columbia, S. C., in an outbreak of fall army worms. Numbers of parasitized larvae were collected, and the duration of the pupal stage was determined. Data on the number of adults issuing from one host were also obtained. Some of the results obtained are given in Table 21. Altogether 135 parasitized larvae were collected. Moths issued from 8 per cent of this number; tachinids issued from more than 50 per cent of the number, and the remainder died.

TABLE 21.—*Duration of the pupal stage of Winthemia quadripustulata, August, 1920, with Laphygma frugiperda as a host; also the number of flies reared from one larva*

Host No.	Date host was collected	Date parasites emerged and pupated	Number of parasites from one host	Number of flies	Date flies issued	Length of pupal stage	Average mean temperature
						Days	*° F.*
1	Aug. 5	Aug. 12	2	2	Aug. 20	8	82.7
2	do	Aug. 10	1	1	Aug. 21	11	82.1
3	do	Aug. 12	1	1	Aug. 20	8	82.7
4	do	Aug. 10	1	1	do	10	82.2
5	do	Aug. 12	1	1	Aug. 22	10	82.6

TABLE 21.—*Duration of the pupal stage of Winthemia quadripustulata, August, 1920, with Laphygma frugiperda as a host; also the number of flies reared from one larva*—Continued

Host No.	Date host was collected	Date parasites emerged and pupated	Number of parasites from one host	Number of flies	Date flies issued	Length of pupal stage	Average mean temperature
						Days	°*F.*
6	Aug. 5	Aug. 10	2	1 1	Aug. 19 Aug. 21	9 11	82.1 82.5
7	do	Aug. 12	1	1	Aug. 20	8	82.7
8	do	do	1	1	Aug. 21	9	82.5
9	do	do	1	1	Aug. 22	10	82.6
10	do	Aug. 10	1	1	Aug. 19	9	82.1
11	do	Aug. 12	2	1 1	do Aug. 20	7 8	82.1 82.7
12	do	Aug. 10	2	1 1	do Aug. 21	10 11	82.2 82.1
13	do	Aug. 12	1	1	Aug. 20	8	82.7
14	do	do	2	2	do	8	82.7
15	do	do	2	1 1	Aug. 19 Aug. 21	7 9	82.6 82.5
16	do	Aug. 10 Aug. 12	2	1 1	Aug. 19 Aug. 21	9 9	82.1 82.5
17	Aug. 10	Aug. 14	1	1	Aug. 24	10	82.9
18	do	Aug. 17	1	1	Aug. 26	9	82.9
19	do	do	1	1	do	9	82.9
20	do	Aug. 15	1	1	Aug. 25	10	82.9
21	do	Aug. 16	1	1	Aug. 26	10	83.1
22	Aug. 11	Aug. 18	1	1	Aug. 29	11	81.9
23	do	Aug. 16	1	1	Aug. 26	10	83.0
24	Aug. 13	Aug. 17	2	2	do	9	82.9
25	do	do Aug. 18	2	1 1	Aug. 25 Aug. 26	8 8	83.2 82.7
Average						9.05	82.6

Other species of Tachinidae have been reared from Laphygma in various parts of the country. These are mentioned below.

The interesting parasite *Archytas piliventris* Van der Wulp (fig. 45) is indigenous to Texas and has been reared very often from Laphygma larvae at the entomological laboratory at Brownsville. Aldrich reports it from Waco, Tex. It is especially common during the fall months, although it has been reared during other periods of the year. The rate of parasitism may reach 20 per cent but usually is not over 5 per cent. The female deposits living larvae on the foliage of plants upon which the host is feeding. The maggots are bluish green in color and lie close to the leaves until disturbed, when they rear up, stand erect, and wave their heads about. One fly was observed to deposit 15 maggots in 60 seconds. When a caterpillar crawls over one of these maggots the maggot attaches itself to the caterpillar and enters its body. A favorite place of entrance appears to be just back of a proleg. The host pupates normally, and the adult parasite emerges from the pupa. But one adult parasite emerges from one host.

Vickery's observation indicates that the shortest time between oviposition and emergence for this species, in 25 individuals, was 25 days, during October and November, at an average mean temperature of 75° F. During December and January the time spent in the pupal stage alone was 51 days at an average mean temperature of 61.5°. The pupal stage in April and May was 21 days. E. G. Smyth observed that the time elapsing between the pupation of Laphygma larvae and the emergence of *A. piliventris* in 12 individuals was from 14 to 16 days, in June, at an average mean temperature of 79° F.

Van Dine (*62*) reared this species from *Laphygma frugiperda* in 1912 in Porto Rico, and Mel T. Cook, under date of August 11, 1905, wrote from Santiago, Cuba, that he reared this parasite from the same host.

An adult of *Phorocera claripennis* Macq. (fig. 46) was reared by E. A. McGregor August 14, 1912, from a Laphygma pupa collected at Leesville, S. C., and by G. G. Ainslie on September 16 of the same year, from a larva collected at Grand Bay, Ala.

R. J. Kewley, at Columbia, S. C., on August 8, 1916, collected a fall army worm, which entered the soil August 10. On August 15

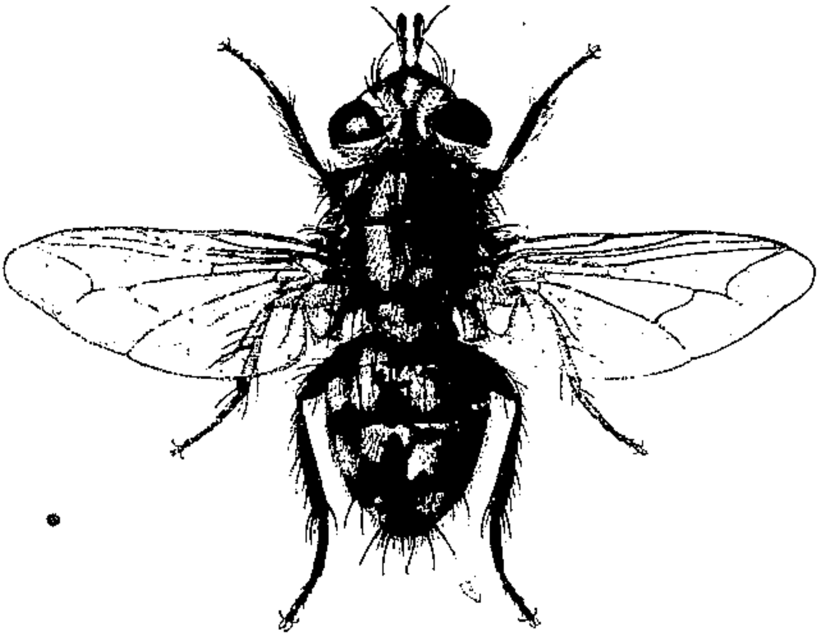

FIG. 45.—Adult of *Archytas piliventris*, parasite of the fall army worm. Greatly enlarged. (Walton and Luginbill)

a puparium was found. The fly issued August 23 and was determined by J. M. Aldrich.

On August 6, 1914, J. S. Wade reared an adult of *Archytas analis* Fab. from a Laphygma larva taken at Mead, Kans., July 18. Other specimens of this parasite were reared at Wellington, Kans., by T. S. Wilson on September 2 and 23, and October 1, 1914.

An adult of *Phorocera floridensis* Town. was reared from a fall army worm at Columbia, S. C., September 1, 1920. The determination of the insect was made by J. M. Aldrich.

Hyphantrophaga hyphantriae Town. was reared from a fall army worm collected at Chillocothe, Tex., by T. D. Urbahns on August 30, 1912; the larva emerged and pupated on September 7, the adult emerging September 20. The fly was determined by W. R. Walton.

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An adult of *Frontina archippivora* Will. was reared by T. D. Urbahns September 19, 1912, from a Laphygma larva collected at Chillocothe, Tex., on August 30. The maggot pupated on September 10. R. A. Vickery reared it at Brownsville, Tex. According to Van Dine (*62*), it has been reared from Laphygma in Porto Rico. Aldrich reared the species from *Laphygma flavimaculata* Harv., *Pyrameis cardui* L., and *Vanessa antiopa L.* at Moscow, Idaho.

According to Chittenden (*7*), *Frontina frenchii* Will. was reared by Howard from a Laphygma larva collected at Columbia, S. C., in September.

Admontia degeerioides Coq. was reared at Brownsville, Tex., from a Laphygma larva received from Glen Herrick of Cornell University on September 13, 1912. The determination was made by W. R. Walton.

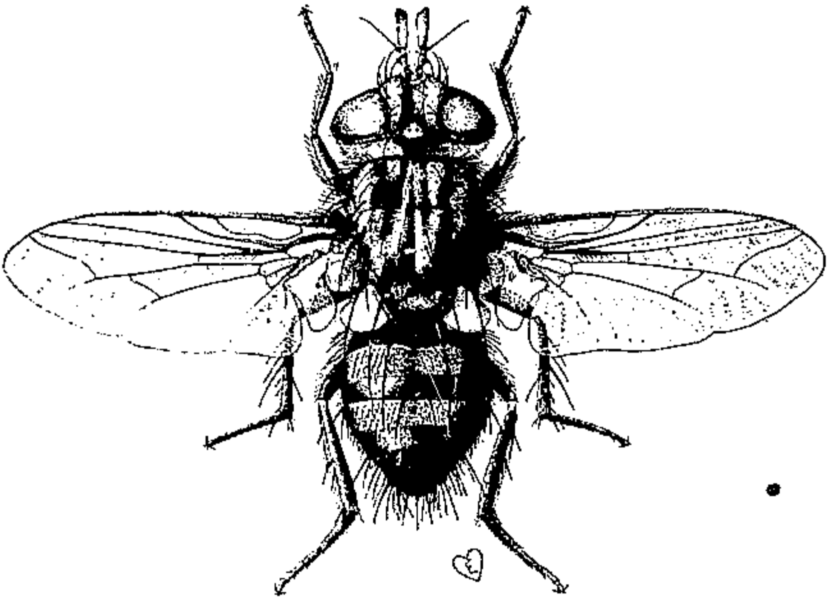

FIG. 40.—*Phorocera claripennis*, a parasite of the fall army worm. (Wildermuth)

Exorista ceratomiae Coq. was reared October 21 from a Laphygma larva collected September 30, 1912, at Memphis, Tenn. The determination was made by W. R. Walton.

Gonia crassicornis Fab. was reared by Van Dine (*62*) in Porto Rico, in 1912, from a fall army worm, and determined by W. R. Walton.

According to Coquillett (*11*), *Gonia capitata* De Geer is also a parasite of Laphygma.

Exorista pyste Walker is mentioned by Wilson (*66, p. 5*) as an enemy of the fall army worm in St. Croix, Virgin Islands.

SARCOPHAGIDAE

E. A. McGregor reports having reared a specimen of *Sarcophaga assidua* Walker from a pupa of the fall army worm at Batesburg, S. C., during 1912.

PREDACIOUS ENEMIES

COLEOPTERA

Chief among the predacious enemies of the fall army worm are the Carabidae, especially those belonging to the genus Calosoma. Both the larval and adult stages of Calosoma feed on Laphygma larvae. However, the beetles are in the larval stage when the caterpillars are most abundant and do not become adult until late summer. They hibernate as adults, and probably there is but one generation per year.

Calosoma larvae were found feeding on fall army worms in various parts of the country in 1912. The writer first noticed them at St. Matthews, S. C., during late July of that year. Specimens captured and placed in receptacles with Laphygma larvae devoured them immediately. In the following year Calosoma larvae were more abundant than in 1912. These predators were abundant at Columbia, S. C., in a millet patch which was heavily infested with Laphygma, especially under the millet that had fallen. The soil in such places was honeycombed by the predators. No Laphygma larvae and only a few pupae could be found in such places.

Three species of this genus are known to be predacious on the fall army worm in the United States, namely, *C. calidum* Fab., *C. scrutator* Fab., and *C. sayi* Dej.

Calosoma calidum Fab. is the most common of the three species of Calosoma given above and has been repeatedly found associated with the fall and true army worms. In fact, during a recent outbreak of the latter, in crabgrass and cowpeas at Columbia, S. C., this species proved very efficient in controlling the pest.

Calosoma scrutator Fab. has been found associated with Laphygma larvae in the South, but does not appear to be as common as *C. calidum*.

R. N. Wilson obtained an adult of *Calosoma sayi* Dej. from a larva collected in a field which was badly infested with Laphygma, near Gainesville, Fla. The adult was determined by E. A. Schwarz.

In Porto Rico, Van Dine found *C. alternans* Web. feeding on a Laphygma larva.

Three other species of ground beetles feed on the fall army worm, according to Hinds and Dew (*31*) and Dew (*12*). These are *Lebia analis* De Geer, *Galerita bicolor* Drury, and *Callida punctata* Lec.

Other coleopterous enemies of the insect are the tiger beetles, of which *Tetracha carolina* L. has been found to be the most common. This species has been observed to feed on the larvae.

Harpalus pennsylvanicus Dej. was found feeding on a Laphygma larva in a burrow at Memphis, Tenn., on September 30, 1912, by W. R. McConnell.

HEMIPTERA

Four species of insects belonging to the order Hemiptera, suborder Heteroptera, have been found to be abundant in some districts where the fall army worm occurs and have often been observed to feed on Laphygma larvae. The two principal species are *Apateticus maculiventris* Say and *Triphleps insidiosus* Say.

(*Podisus*) *Apateticus maculiventris* Say (figs. 47, 48, and 49) appears to be the commoner of the two bugs found feeding on Laphygma. As a predatory enemy it probably ranks next to Calosoma beetles. Caterpillars are attacked by the nymphs as well as the adults. Even the moth does not escape the attacks of this bug. McConnell observed an adult of Apateticus sucking a moth of Laphygma at Harde, Miss., August 21, 1912.

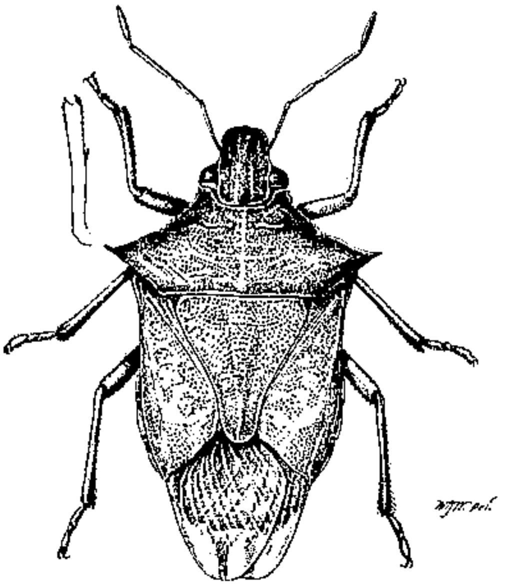

FIG. 47.—The spined soldier bug, *Apateticus maculiventris*, an enemy of the fall army worm; adult bug. Greatly enlarged. (Walton and Luginbill)

Numerous observations of its feeding on Laphygma larvae were made during 1912; by S. E. Crumb at Clarksville, Tenn.; by Dwight Pierce at Mound, La., West Point, Miss., and MacClenny, Fla.; by Harry Pinkus at Opelousas, La., and Mr. Becker at various places in Arkansas.

This bug is a common enemy of other lepidopterous insects and is considered the most useful of our predacious Hemiptera. According to Hart (*27, p. 201*), this bug is an enemy of *Diabrotica duodecimpunctata* Oliv. and *Leptinotarsa decemlineata* Say.

The small bug *Triphleps insidiosus* Say has been found feeding on the larvae of Laphygma; it apparently feeds more often on the eggs of this insect. S. E. Crumb observed this species attacking an injured Laphygma larva at Clarksville, Tenn., on August 23, 1912.

This insect is one of the chief enemies of the corn earworm (*Heliothis obsoleta* Fab.).

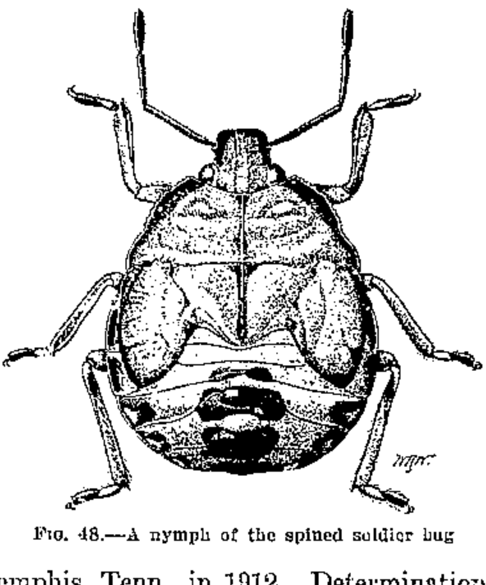

FIG. 48.—A nymph of the spined soldier bug

Nabis ferus L. was observed by T. H. Parks sucking a Laphygma larva at Memphis, Tenn., in 1912. Determination was made by O. H. Heideman.

W. R. McConnell observed a *Sinea sanguisuga* Stål. attacking a Laphygma larva. Determination was made by O. H. Heideman.

MISCELLANEOUS PREDATORS

A larva of a species of Chrysopa was found in a millet field which was infested with Laphygma at Columbia, S. C. It attacked young larvae of Laphygma when given the opportunity.

W. D. Pierce records finding a mass of Laphygma eggs which were attacked by a larva of Chrysopa at Dallas, Tex., September 23, 1912. This larva ate another mass of eggs before it pupated. Pierce determined the species as probably *C. plurabunda* Fitch.

Morgan observed an adult of *Megilla maculata* De Geer, feeding on an egg mass of Laphygma at Memphis, Tenn., July 31, 1912.

Van Dine records this species as predacious on Laphygma larvae in Porto Rico, and R. A. Vickery observed an adult feeding on a pupa of *Sagaritis dubitatus* in the field. The beetle had eaten a hole into the cocoon and removed the pupa. Vickery has observed cocoons destroyed in this way previously.

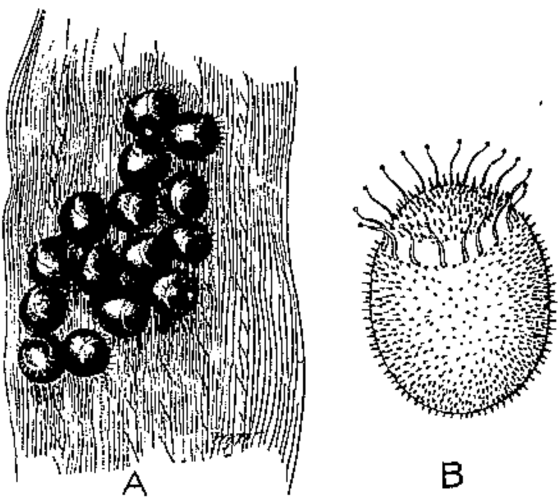

FIG. 40.—A, eggs of the spined soldier bug on a leaf; B, one of the eggs. Much enlarged

C. L. Scott observed *Ceratomegilla fuscilabris* Muls. feeding on the eggs of *Laphygma frugiperda* at Brownsville, Tex., June 2, 1914. He observed it attacking a cocoon of *Sagaritis dubitatus*. From a collection of 90 Sagaritis cocoons made by Scott, 30 had been injured in this manner. This beetle was observed destroying cocoons of *Euplectrus platyhypenae* and *Apanteles marginiventris* (Cress.) at Brownsville, Tex., on other occasions.

The Meteorus cocoons are not often attacked, as they are suspended by a thread which makes them difficult of access.

W. R. McConnell observed a wasp, determined as *Polistes annularis* L., eating a fall army worm at Hoxie, Ark., on August 13, 1912.

According to Bodkin (*3*), *Polistes nigriceps*[7] performed valuable services in destroying Laphygma larvae in British Guiana during the outbreak in 1912. Van Dine observed an adult feeding on a Laphygma larva in Porto Rico.

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[7] S. A. Rohwer, of the Bureau of Entomology, states that there is no such species belonging to this genus known to him. He suggests that Mr. Bodkin may have referred to *Montezumia nigriceps* (Spinola). In another publication Bodkin (*2*) refers to a *Polybia nigriceps* which may also be the same species. There is no species known as *Polybia nigriceps*.

W. R. McConnell records having observed a wasp, *Vespula carolina* L., holding a Laphygma moth in its grasp at Greenwood, Miss., September 23, 1913.

A species belonging to the genus Sphex (once called Ammophila) was observed feeding on Laphygma larvae by E. R. Barber and other members of the Bureau of Entomology.

W. E. Hinds and also J. A. Dew (*12*, *31*) record having observed this species feeding on these caterpillars in Alabama during 1912.

Various observers have recorded that dragonflies feed on fall army worms.

Various species of ants have been observed feeding on the fall army worm, and they are listed by Wilson (*66*, *p. 5*) as enemies of the fall army worm in St. Croix, Virgin Islands. At Columbia, S. C., it was impossible to rear this species in flowerpot cages on tables until the legs of such tables were placed in pans containing water or oil. Before this was done the ants would crawl up the legs of the tables, work their way inside the cages, pick up the young larvae and carry them away into their lairs. Some cages were almost completely cleared of larvae in this way. The ants attacked not only the larvae in the cages but also those in the fields. Old larvae as well as young ones were attacked and killed. The former when first attacked resisted but soon were overpowered and killed by the large number of antagonists.

One of the species Harry Pinkus observed feeding on the larvae at Nacogdoches, Tex., during 1912 was *Solenopsis geminata* (Fab.), and other specimens devouring Laphygma larvae, near Gainesville, Fla., during July, 1915, were determined as *Solenopsis geminata* Say, subspecies *xyloni* Fab.

According to T. E. Holloway, the Argentine ant (*Iridomyrmex humilis* Mayr) has been observed to attack the fall army worm.

Another species, *Pogonomyrmex barbatus* Smith (Mayr), has been observed by T. S. Wilson to carry away young larvae of this species.

Various species of spiders have been observed to feed on Laphygma larvae, and on one occasion a mite attacked and killed a larva.

VERTEBRATES

Among the predacious vertebrate enemies of the fall army worm the mammals, amphibians, and birds play an important rôle in the destruction of this pest.

MAMMALS

The skunk (*Mephitis nigra* Peale and Beauvois) is known to feed on both the larval and pupal stages of this insect.

REPTILES

Wilson (*66*, *p. 5*) mentions lizards as enemies of the fall army worm in St. Croix, Virgin Islands.

AMPHIBIANS

The most common enemy of the fall army worm among the amphibians in the South is the little, green tree frog, *Hyla semifasciata cinera* Daudin. According to W. D. Pierce, Harry Pinkus observed this species feeding commonly on the larvae at Lafayette and Opelousas, La., in 1912; and G. D. Smith made similar observations at St. Joseph, Videlia, and Tallulah, La.

On one occasion it was noticed that a number of frogs, apparently of this species, devoured Laphygma larvae as they dropped into trap furrows. The frogs gathered in the furrows and ate the larvae in large quantities, making it impossible to employ the log drag without crushing them.

On several occasions the common toad, probably *Bufo lentignosus* Shaw., was observed to feed on larvae of this insect, while Bodkin (*2*) records *B. marinus* as predacious on the caterpillars in British Guiana.

BIRDS

NATIVE WILD BIRDS

A number of different species of birds have been observed to feed on Laphygma in the United States. The list of these species includes the following:

Killdeer (*Oxyechus vociferus vociferus* L.).
Partridge or quail (*Colinus virginianus virginianus* L.).
Flicker (*Colaptes auratus* L.).
Crow (*Corvus brachyrhynchos brachyrhynchos* Brehm).
Blue jay (*Cyanocitta cristata cristata* L.).
Red-winged blackbird (*Agelaius phoeniceus phoeniceus* L.).
Crow blackbird or purple grackle (*Quiscalus quiscula quiscula* L.).
Boat-tailed grackle (*Megaquiscalus major major* Vieill.).
Meadowlark or field lark (*Sturnella magna magna* L.).
English sparrow or European house sparrow (*Passer domesticus domesticus* L.).
Chipping sparrow (*Spizella passerina passerina* Bechst.).
Mockingbird (*Mimus polyglottos polyglottos* L.).
Bluebird (*Sialia sialis sialis* L.).

The English sparrow has been observed on several occasions to completely eradicate the fall army worm from lawns and other small patches of grass around dwellings. In this respect it benefits the city dweller more than the farmer. During a recent outbreak of Laphygma on the State capitol grounds and on the campus of the University of South Carolina at Columbia the sparrows were observed to collect in flocks and devour the caterpillars in great numbers.

D. F. Ferris, of Summit, Ind., as early as 1842 discovered that crows feed on the fall army worm.

W. B. Hall, at Wakeman, Ohio, in the fall of 1912, on several occasions noticed crows in great numbers feeding on the larvae and pupae. Hall also observed flocks of killdeers and meadowlarks visit the same place for their meals.

In Porto Rico, according to Van Dine, two species of blackbirds prey upon these larvae. These are known as El Judo (*Crotophaga ani*) and El Chango o Mozambique (*Holoquiscalus brachipterus*). According to Bodkin (*3*) the "robin" (*Leistes guianensis*) feeds upon Laphygma larvae in British Guiana.

In the Virgin Islands Wilson (*66, p. 5*) records the gray kingbird (*Tyrannus dominicensis*) and the blackwitch (ani) (*Crotophaga ani*) as feeding on Laphygma. He also mentions several invertebrate enemies.

In San Salvador *Megaquiscalus major macrourus* rendered good service in destroying fall army worms during an outbreak in 1912, according to P. A. Villa Carta. This bird in Mexico is known as "Pajaro Prieto" and in the Central American States as "Sanate." It is considered a granivorous bird and invades cornfields in search of grain; however, on this occasion it assisted the farmers in controlling an insect pest.

DOMESTIC FOWLS

Turkeys, chickens, and other barnyard fowls have been observed repeatedly to feed on the larvae of this insect and aid greatly in controlling the species, especially in lawns around dwellings and near-by pasture lands.

DISEASES

In the late fall of 1912 a disease was observed among some larvae collected in the field at Columbia, S. C. After being kept in receptacles for a short time, the infected larvae turned a pinkish color and died soon afterwards. Almost immediately after death the remains would change into a more or less watery mass. B. R. Coad noticed a disease among Laphygma larvae at Tallulah, La., during 1912. During the same year W. D. Pierce recorded a similar observation for Mississippi, and G. G. Ainslie mentions the presence of a disease of these larvae late in the fall of 1914 at Nashville, Tenn. *Laphygma frugiperda* larvae similarly affected were collected also during the late summer of 1920 at Columbia, S. C.

Dead larvae of this insect supporting a fungous growth were found at Brownsville, Tex., by R. A. Vickery during November, 1913, and at varous times during the following year. He observed that the fourth and fifth instars are most often attacked. One fungus which has been found attacking these larvae is *Botrytis rileyi* Farlon. J. A. Hyslop collected such a larva at Winchester, Va., August 15, 1914. According to Van Dine, two species of parasitic fungi are prevalent among Laphygma larvae in Porto Rico. These are a species of Botrytis and a species of Empusa.

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