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& Insects

U. S. DEPARTMENT OF AGRICULTURE.

DIVISION OF ENTOMOLOGY—BULLETIN NO. 41.

L. O. HOWARD, Entomologist.

THE CODLING MOTH.

PREPARED UNDER THE DIRECTION OF THE ENTOMOLOGIST

BY

C. B. SIMPSON,

Special Field Agent.

234755

National Museum

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1903.

Corrected to December, 1897.

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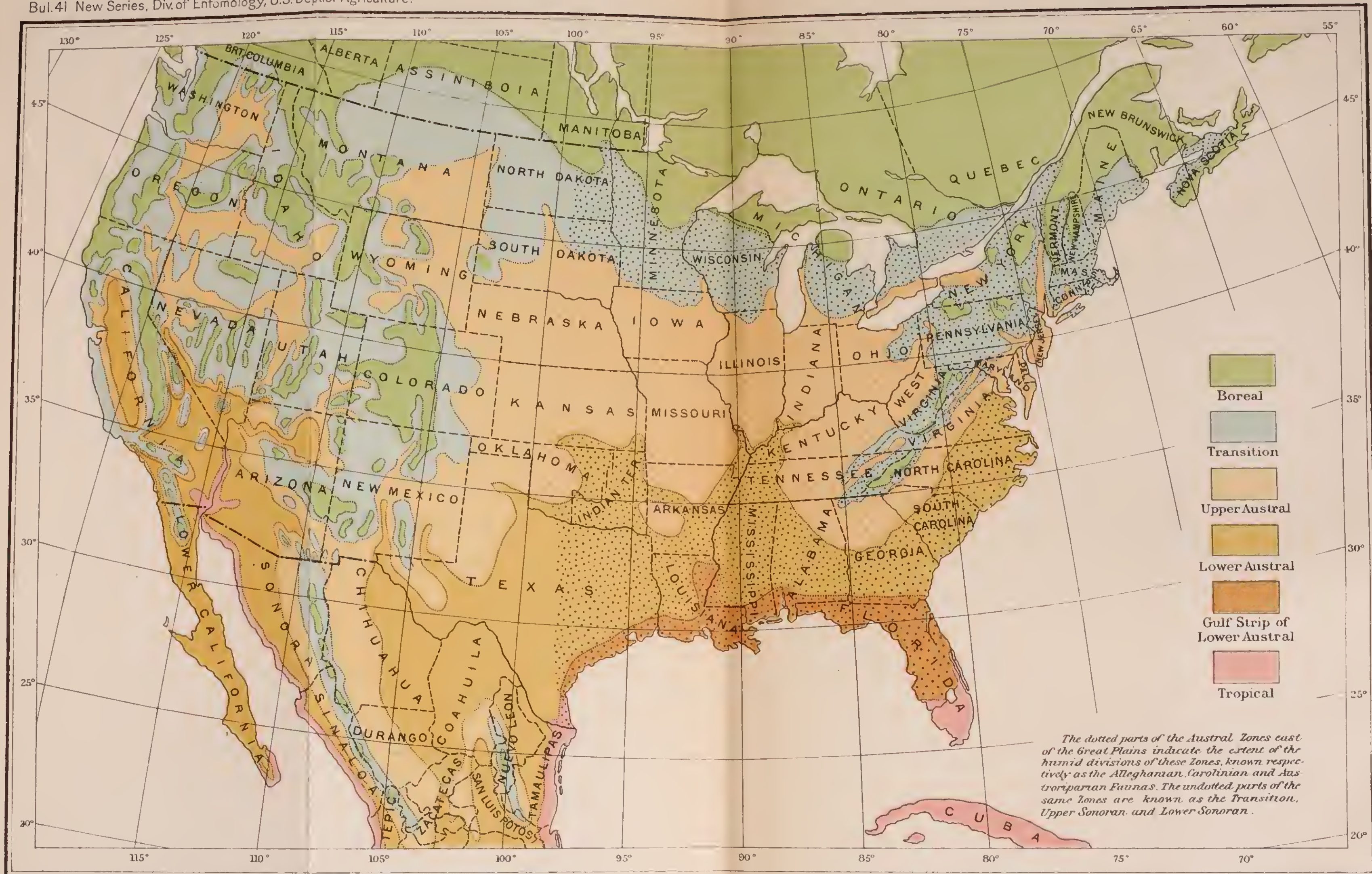

Corrected to December, 1897.

LIFE ZONES OF THE UNITED STATES

BY

C. HART MERRIAM

DIVISION OF ENTOMOLOGY.

L. O. Howard, *Entomologist.*

C. L. Marlatt, *in charge of experimental field work.*
F. H. Chittenden, *in charge of breeding experiments.*
A. D. Hopkins, *in charge of forest insect investigations.*
Frank Benton, *in charge of apiculture.*
W. D. Hunter, *in charge of cotton-boll weevil investigations.*
D. W. Coquillett, Th. Pergande, Nathan Banks, *Assistant Entomologists.*
E. A. Schwarz, E. S. G. Titus, *Investigators.*
Miss H. A. Kelly, *Special agent in silk investigations.*
R. S. Clifton, F. C. Pratt, August Busck, Otto Heidemann, A. N. Caudell, J. Kotinsky, H. G. Barber, *Assistants.*
W. E. Hinds, W. F. Fiske, A. L. Quaintance, G. H. Harris, H. E. Burke, A. W. Morrill, *Temporary field agents.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Entomology,
Washington, D. C., July 29, 1903.

Sir: I transmit herewith the manuscript of a report on the codling moth, prepared under my direction by Mr. C. B. Simpson, field agent of this Division. Mr. Simpson had been charged with a special investigation of the codling moth, more particularly in the Northwest, in answer to special requests for such study in the newly developing fruit interests of that region. The codling moth is undoubtedly the most important insect pest of apple and pear, and is the occasion of greater loss than all the other insect enemies of these fruits combined, entailing an annual shrinkage of values exceeding $11,000,000. Mr. Simpson's investigations covered a period exceeding two years, and have already been voiced in a small preliminary bulletin and in a Farmers' Bulletin giving condensed advice relative to the control of this insect. The present publication is the final and complete report, elaborating all of the conclusions and results of this special investigation. It will be a very useful document for all workers in applied entomology and of decided practical value for the fruit grower. The illustrations which accompany it are essential to the correct understanding of the experiments reported and of the text. I recommend that this report be published as Bulletin No. 41 of the Division of Entomology. As stated in the letter of transmittal of bulletin No. 40, the term "New Series" has been dropped.

Respectfully,

L. O. Howard,
Entomologist.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

THE CODLING MOTH.

(*Carpocapsa pomonella* Linn.)

INTRODUCTION.

Every person is acquainted with "wormy apples," and many have seen the caterpillars in the fruit, while few know the history of the worm-like creature which causes the injury, or whence it comes or whither it goes.

If apple insects were classified in the order of the degree and extent to which they cause monetary loss, the codling moth would rank first, since it causes more injury than all other insect enemies of this fruit combined. It is the most serious drawback with which the apple grower has to contend, as from one-fourth to one-half of the apple crop of the United States is injured every year. The control of this pest, however, is not difficult when compared with that of many other insects, and hosts of apple growers are each year saving practically all of their crop from its ravages.

In the literature of the subject, one finds that Cato makes the first mention of this insect, and since that time almost every entomologist has studied it and written about it. By the writings of LeBaron, Walsh, Riley, Cook, Goff, Forbes, Howard, Slingerland, and many others, information about its life history and remedial measures has been disseminated, which have facilitated its control in the eastern part of the United States.

It was found that in the western United States the conditions were different from those in the East and that the recommendations which brought success in the East did not give satisfactory results in the West, and the necessity arose of making a close study of the western conditions. Among those who have written on the insect in the West are Messrs. Washburn, Koebele, Card, Aldrich, Gillette, Cordley, and Cooley.

The two principal accounts of this insect are those by Dr. L. O. Howard in 1888 and Prof. M. V. Slingerland in 1898. Both of these writings give a summary of what was known of the insect at those dates, with many original observations and suggestions for its control.

Slingerland's bulletin is especially comprehensive, partly because of the late date of its publication, and partly because a complete bibliography and valuable historical notes are given. The excellent observations and photographs are important features of this publication, which has been of the greatest assistance to the writer of this bulletin.

The writer is under obligation to many for the aid given in this work. Hon. Edgar Wilson, Hon. Fremont Wood, and Mr. W. F. Cash rendered assistance in carrying out the practical tests; Mr. Alex. McPherson, the State horticultural inspector, made observations and gave aid in many ways; Mr. S. M. Blandford, of the United States Weather Bureau, at Boise, kindly furnished the temperature data used; Mr. H. E. Burke, of the Department of Agriculture, assisted in the work in 1902, and did much valuable and accurate work upon the life history of the insect; Prof. C. P. Gillette and Mr. D. W. Coquillett kindly gave the writer access to their notes. Many fruit growers in Idaho have rendered especially valuable aid in keeping records. Professor Slingerland granted permission to use many of his figures, and his bibliography, with his notes, is used as a foundation for that portion of this bulletin. Prof. J. M. Aldrich, Prof. A. B. Cordley, and Prof. C. V. Piper have at all times given aid, counsel, and advice, and granted permission to use their unpublished data.

The estimates of injuries inflicted by the codling moth given in this bulletin are based principally upon observations made upon check trees in spraying experiments.

SYSTEMATIC POSITION.

The codling moth belongs to the order Lepidoptera, or scale-bearing insects, and has been assigned to the family Tortricidæ. The description of the genus *Carpocapsa* Treitschke, as given by Meyrick, is as follows:

> Antennæ in ♂ simple. Palpi moderate, curved, ascending. Thorax smooth. Forewings with termen slightly sinuate. Hindwings in ♂ with longitudinal groove below cell, including a hair pencil; 3 and 4 connate or stalked, 5 nearly parallel to 4, 6 and 7 closely approximated toward base. A small but rather widely distributed genus. * * *

The species *pomonella* is distinguished from the other species by having the margin of the ocellus (or black spot on the wing) of a coppery metallic color. (See Pl. VII.) The description of *pomonella* is given by Meyrick as follows:

> 14–19 mm. Forewings dark fuscous, finely irrorated with whitish, with darker striæ; basal patch sometimes darker; a large dark coppery brown terminal patch hardly reaching costa, anterior edge more blackish, ocellos within this edged with bright coppery metallic. Hindwings fuscous, darker terminally.

NAMES OF THE INSECT.

POPULAR NAMES.

The name "codling moth" is the one most generally used by the American fruit growers. The first name given to this insect was "pear eater," on account of its feeding in pears. Later writers called it the "apple and pear worm or moth," "fruit worm," "fruit moth," and many others names. The name "apple worm" is often used, especially by the English.

Wilkes, an English author, first used the name in 1747, which name was taken from a kind of apple tree. Slingerland says that the word "codling" is doubtless a corruption of the old English word "querdlying," which means any immature or half-grown apple. Some horticulturists and entomologists and others use the names "coddling" or "codlin." As a result of extended research Slingerland discards these names and gives the name "codling" decided preference.

SCIENTIFIC NAMES.

In 1758 Linnæus gave this insect the specific name of *pomonella* and the discription is as follows: "Alis nebulosis postice macula rubra aurea." Schiffermüller, 1776, named it "pomonana." Fabricius, 1793, gave it the name "pomona." By reason of the eighteen years priority the name "pomonella" stands.

Linnæus gave this insect the generic name of *Tinea*. Later it was known as *Pyralis*, *Tortrix*, *Semasia*, and *Erminea*. Still later it was given the name *Carpocapsa*, which was in use for about three-quarters of a century. In 1897 Walsingham concluded that the name *Carpocapsa* must fall and be replaced by *Cydia*. This view was adopted by Fernald in Dyar's list of North American Lepidoptera; but Cockerell strongly doubted this conclusion. After a very exhaustive study of the subject Mr. Busck concludes that the old name *Carpocapsa* is the proper name and must be restored, and his conclusions are accepted in this publication.

VARIETIES OF CODLING MOTH.

Staudinger described a variety of the codling moth which was bred from either apple or walnut in which the coppery spots in the ocellus were more broken and gave it the name of *putaminana*.

It has evidently been thought for many years that there was a variety of the codling moth in the far west. Matthew Cooke said in 1883: "From investigation it is probable that there are more than one species of codling moth infesting the fruit of this State [California], but I am not prepared to report at the present writing."

In 1900 the writer found one buff-colored moth which, except for color, was like the common codling moth, on the trunk of a tree at

Boise, Idaho. During 1901 four well-preserved specimens and eight badly worn specimens were secured. In 1902 six of these buff-colored moths were bred among 182 normal moths. In material collected in Idaho in the fall of 1902, from which about 30 moths emerged the following spring, five were of this variety. Mr. A. F. Hitt, of Weiser, Idaho, and Mr. Alex. McPherson, tell the writer that they have noticed these buff-colored moths. Mr. Hitt, in 1896, bred seven of these among 50 normal moths.

The writer submitted the moths to Mr. August Busck, of the United States Department of Agriculture, for determination, and in the Proceedings of the Entomological Society of Washington he describes them as follows:

These specimens were submitted to the writer for determination, and I have carefully examinedt hem structurally in comparison with the common form of *Cydia* ([a]) *pomonella* Linné. I do not think there can be any doubt about their being this species; the oral parts, the venation, the secondary male sexual character of the hind wing, and the external sexual organs of both sexes are identically as found in the common dark form of the codling moth. The general pattern of ornamentation is also the same, but the coloration is so strikingly different that the variety deserves a special name, the more so as no intermediate forms seem to occur. I propose that it be known as *Cydia* ([1]) *pomonella* Linné, var. *simpsonii*.

Instead of the dark fuscous color of the common form, the variety is light buff, with slightly darker buff transverse striation. In the common form the forewings are finely irrorated with white, each scale being slightly white tipped; in *simpsonii* the scales are not white tipped. The terminal patch, which in the common form is dark coppery brown, nearly black, and with dark violaceous metallic streaks, is in *simpsonii* light fawn brown with pure golden metallic streaks. The extreme apical edge before the cilia is in the common form black, in the variety reddish brown, and the cilia in *simpsonii* are light golden ocherous instead of the dark fuscous of the common form. The head, palpi, body, legs, and the tuft of hairs on the hind wings of the male are correspondingly light-buff colored in the variety instead of dark fuscous, as in the common form.

Besides Mr. Simpson's specimens, in which both sexes are equally represented, there is in the United States National Museum a single female, labeled "Cook, California, July 30, 1883."

Type: No. 6803, United States National Museum.

The writer has never observed any gradations between this variety and the common form. It is most probable that this variety is distinctly western, as there are no records of its having been bred in the East. No attempt was made to secure the earlier stages of the insect, and, as far as observations were made, its life history is similar to that of the normal form of the codling moth, as the larvæ from which this variety was bred were taken with the larvæ of the normal form under bands on apple trees. One might theorize on what conditions in the West have given rise to this new variety, but to state with any degree

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[a] The generic name *Cydia* used by Mr. Busck before his investigations, which resulted in the restoration of the old name *Carpocapsa*.

of certainty exactly what has brought about this change is impossible from the data at hand.

GEOGRAPHICAL DISTRIBUTION.

The original home of the codling moth is not definitely known, but is supposed to be southeastern Europe, the home of the apple. It has followed the distribution of the apple closely until it is now present, with but few exceptions, in all countries where apples are grown. It has spread over Europe, and is present as far as the apple region extends in Siberia. It was noted in Australia about 1855, Tasmania about 1861, New Zealand in 1874, South Africa about 1885, and Zeller received it from Brazil in 1891.

Mr. C. L. Marlatt reports that he did not observe this insect in either Japan or China in his extended travels in those regions. Mr. George W. Compere also states that he has never observed it in China. Prof. A. B. Cordley states that this insect has reached China. Evidently some correspondent of his has reported it as present in that country. As apples are being continually shipped to both Japan and China, it is but a question of a few years when it will either be introduced or become injurious in the orchards of those countries.

Extended researches of many investigators have failed to give date or definite information as to the time and manner of introduction of the codling moth into America. For a long time injury to the apple by this insect was thought to be the work of the plum curculio; and it was not till 1819 that the codling moth was reared from wormy apples by Burrell. It was evidently quite well distributed in the eastern United States before its work was identified, as there are but few records of its spread. In 1840 it was a serious pest in New England and central New York. About 1860 it invaded Iowa. For many years it has been a serious pest in Canada. Mr. Alexander Craw stated in 1893 that the insect was first introduced into California by means of some fruit brought from the East to Sacramento for exhibition purposes in 1872. No measures were taken to destroy the insects in this fruit, and two years later its presence in abundance was noted. Later it was rapidly distributed over the State, aided by the system of returning boxes. Dr. C. V. Riley mentions in 1876 that this insect was then present in Utah, where it had evidently been introduced a year or two previously.

From these points of infestation the codling moth spread over the Western States. Prof. J. M. Aldrich states that it has been known in the Clearwater Valley in Idaho since 1887. Mr. I. L. Tiner, of Boise, states that in 1887 he found the first indication of this insect at Boise, Idaho. Mr. Thomas Davis, of Boise, states that it was introduced into his orchard at about the same time.

RELATION OF DISTRIBUTION TO LIFE ZONES.

Although the codling moth may be brought into a section of country, it may not be able to obtain a foothold on account of the adverse climate. In other regions it is never very injurious, or it may be quite injurious one year and almost absent the next; but in warmer regions it reaches the maximum of destructiveness.

In order to study these conditions the writer has used the life zones of Dr. C. Hart Merriam (Pl. I). Upon consulting this map one finds that there are seven different zones in the United States. In the eastern portion they, in a general way, extend east and west, while in the western part they are broken into irregular areas by the mountain ranges. There are many important subdivisions of these zones, depending principally upon the amount of moisture and the milder and more temperate climate near the seacoasts.

BOREAL ZONE.

The principal apple-growing regions of this zone are in Nova Scotia, northern Maine, northern Michigan, and western Oregon. Except for the Pacific coast strip, only the more hardy varieties of apples are grown in this zone. There is a great lack of definite data in regard to the exact amount of injury the insect causes in this zone. As near as the writer can learn, the injury is never so great as it is in the next warmer zone. According to Cordley, the insect is present in small numbers in the Pacific coast strip and is doing but a comparatively small amount of injury.

TRANSITION ZONE.

The transition zone includes the greatest apple-producing regions of the United States, the Alleghenian area comprising the zone in the eastern mountain States, including the larger part of the apple-growing regions of New York, Pennsylvania, and Michigan. Although the injury, which varies with the seasons, is greater in the transition than in the boreal zone and less than in the austral, no record of definite percentages has been found during the present study.

In the arid area of the transition zone the loss is less than in the Alleghenian area. Various estimates of from 5 to 25 per cent of damage have been given. At Moscow, Idaho, which partakes more of the Pacific coast strip characteristics than of those of the arid area, Professor Aldrich records the amount of injury as 21 per cent for 1899, 10 per cent for 1900, and 5 per cent for 1901. Professor Piper states that in 1898 the average damage about Pullman, Wash., was 10 per cent, and some orchards were injured 25 per cent; in 1902, about 5 per cent. Professor Gillette reports from 35 to 80 per cent at Fort Collins, Colo., varying with the degree of infestation in the locality.

Cooley reports an injury of 95 per cent in small home orchards in Helena, Mont. There are many regions in this faunal area in which the insect does about 25 per cent damage, and for some reason, probably climatic, the injury is reduced to almost nothing for several years, after which the numbers of the insect gradually increase. Professor Aldrich records that in 1899 an early snowfall and low temperature at Moscow, Idaho, killed a great many of the larvæ. There are many other localities in the Pacific Northwest where the codling moth either has not been introduced or has not thrived, and in which the injury is nominal.

In many regions where the transition zone is pierced by valleys of the upper Sonoran zone the orchards near the canyons suffer much greater injury than those more remote therefrom. Professor Piper has noted several cases in which this was true, and in one the damage was 75 per cent or over.

THE PACIFIC COAST TRANSITIONAL AREA.

This area includes those portions of Oregon and Washington between the Coast Mountains and the Cascade Range, parts of northern California, and most of the coast region of the State from near Cape Mendocino southward to the Santa Barbara Mountains. In Oregon varying percentages of injury have been reported, ranging from a nominal loss to 75 per cent. In the Hood River Valley in some cases it is greater than this, with an average, perhaps, of about 25 to 90 per cent.

UPPER AUSTRAL ZONE.

The upper austral zone is divided into two areas by reason of the greater humidity of the eastern portion.

THE CAROLINIAN FAUNAL AREA.

This area includes the great apple regions of the Central States and many smaller portions of the Eastern States. Many entomologists have reported injury in these areas as ranging from 30 or 50 per cent to practically 100 per cent.

UPPER SONORAN FAUNAL AREA.

This area includes that portion of the upper austral zone west of the one hundredth meridian. From many countings and estimates from various sources we find that in badly infested districts the injury varies from 80 to 95 per cent under normal conditions, and it is very common to find the loss reach 100 per cent.

LOWER AUSTRAL ZONE.

In this zone there are only a few localities where apples are grown on a commercial scale. Under normal conditions in badly infested localities the loss is almost total. Garcia records, from check trees in spraying experiments, that the loss varied from 67 to 99 per cent. There are many localities in this zone in both east and west where apples can be grown, but on account of the injuries due to the codling moth other crops are grown instead.

IMMUNE REGIONS.

In many regions of the Far West one often hears the fruit growers say that on account of the peculiar climatic conditions of that region apples are free from injury and the codling moth can not exist. Among these climatic conditions quoted are dense fogs, mountain breezes, and comparatively high altitudes. Seven or eight years ago it was thought that the Hood River Valley was immune from the insect; the same was thought of the Pajora Valley in California; but later developments have shown that immunity was due to the fact that the insect had not been introduced into those localities. It has also been said that there was no codling moth near the coast in Oregon, but Professor Cordley finds that it is present in some localities and believes that the former immunity was due to isolation.

In many restricted areas in the Pacific Northwest more or less isolated the codling moth is either absent or present in such small numbers that it has not been observed. From past experience and examination of these localities it is evident that the insect in its general spread has not yet reached them. It is a question whether or not the insect will be injurious in these localities, but it is certain that it can be present. The writer has no hesitancy in concluding that there is no region in the Pacific Northwest in which apples are grown in which the codling moth can not exist.

Many causes of immunity by isolation in river valleys have been noted. The most marked case is at Mr. I. B. Perrine's orchard at Blue Lake, Idaho. The nearest orchard is 18 miles distant down Snake River, while there are no orchards in the other direction inside of 75 to 80 miles. This orchard was free from codling moth until three or four years ago, the larvæ having undoubtedly been introduced in old apple boxes about that time.

MEANS OF SPREAD.

There are several ways in which the codling moth can be distributed. The most prolific source of distribution comes from the shipping of fruit from an infested region. Fruit which contains the larval insects may be shipped great distances, and when the larvæ complete their growth they spin cocoons, and in due time the moths emerge, and with unerring instinct seek the nearest apple trees. Many larvæ are found to have spun their cocoons in the angles and cracks of the boxes

FIG. 1.—APPLE LEAF INHABITED BY CODLING MOTH.

a, Point where larva entered midrib, at junction with one of the principal veins; *b*, portion of burrow exposed (photograph by Prof. A. B. Cordley).

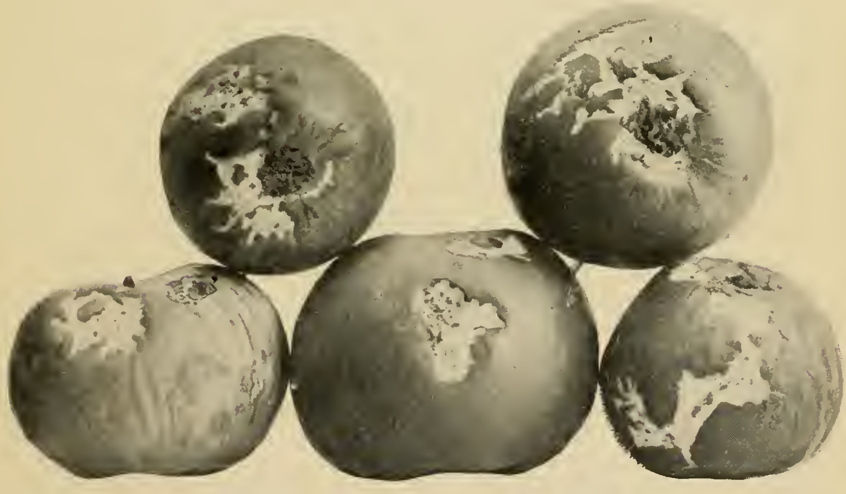
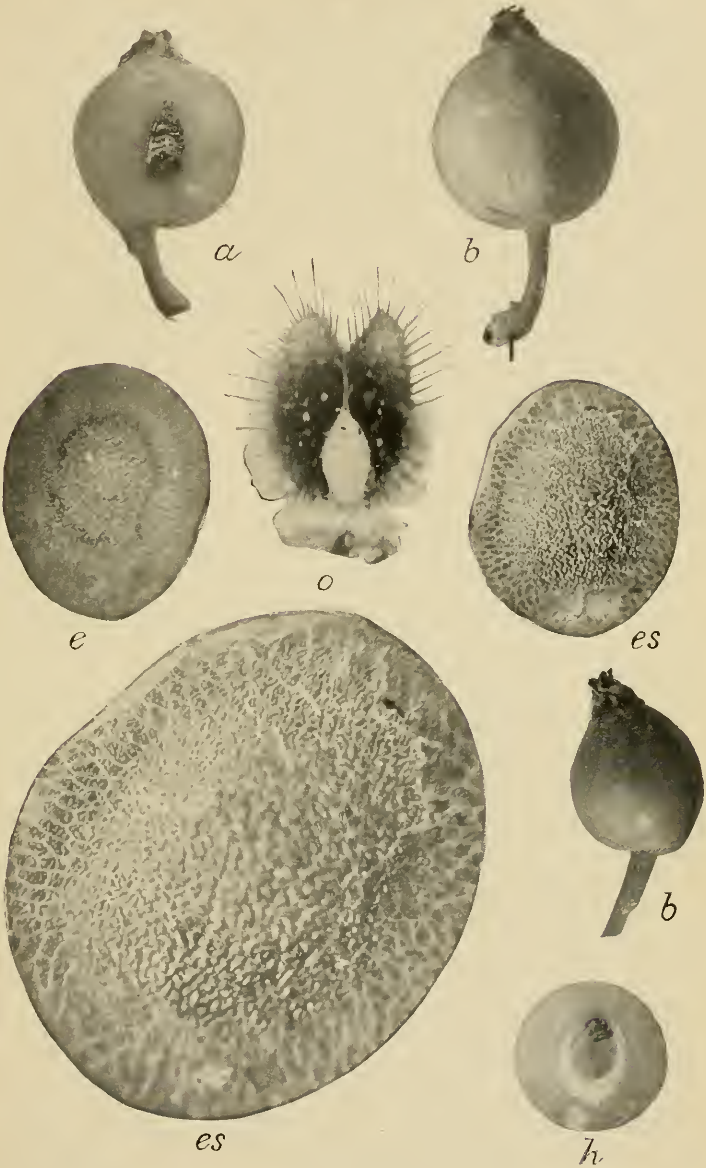


FIG. 2.—APPLES DAMAGED BY UNKNOWN CATERPILLAR.

(Reduced from photograph by the author.)



EGGS OF THE CODLING MOTH.

Natural size of eggs at *a* and *b*; *e*, showing red ring in egg; *es*, egg, showing the hole through which the larva emerged; *h*, showing the egg enlarged, with the larva inside; *o*, the end of the ovipositor of the female. (From Slingerland.)

or barrels. In many localities it has been the practice to return to the fruit grower for refilling boxes in which fruit has been marketed. This practice has supplied the means of rapid distribution in such ocalities.

If infested fruit is shipped any distance in cars the larvæ spin their cocoons in cracks and holes in the walls of the car and may be carried great distances before the moths emerge. This is thought to have been the source of the infestation at Kalispell, Mont.

When apples are stored by commission houses the larvæ may crawl into boxes or cases of various kinds of merchandise and thus be widely distributed.

In sections where the orchards are near each other the spread is accomplished by the moth flying from one to another; but when they are many miles apart, which is especially the case in the Far West, this means of distribution doubtless has little influence. The insect can probably fly a few miles with the aid of the wind, but ordinarily 4 to 6 miles from a source of infestation, over unimproved land, gives partial if not complete immunity.

We have no authentic record of the distribution of the codling moth with nursery stock, but one can readily see how this could occur, as the larvæ might be in the cracks in the ground around the trees or might crawl into the packing and thus be carried great distances.

ESTIMATED LOSSES.[a]

Of all the insects affecting the apple the codling moth causes the greatest loss, and many estimates have been made of the damage. In 1889 Professor Forbes indicated an annual loss in the State of Illinois of $2,375,000. It is estimated that in 1892 the insect caused $2,000,000 loss in Nebraska. Professor Slingerland estimated that in 1897 the insect taxed the apple growers of New York $2,500,000 and the pear growers $500,000. In 1900 one-half of the crop of Idaho was damaged, while in 1901 the loss was much greater. Mr. McPherson estimated the loss in Idaho in 1902 as $250,000. In many sections of the Pacific Northwest the annual loss is from 50 to 75 per cent.

From the nature of the case it is most difficult to estimate the annual loss in the United States on account of the many factors which enter into the problem. By taking the estimates of the annual crops of apples as given by the American Agriculturist, it is found that for the years 1898, 1899, 1900, 1901, and 1902 the average crop was 47,000,000 barrels. From 1896 to 1902, inclusive, the average price at New York, Boston, and Chicago on October 20 of each year did not exceed $2. Allowing $1 for packing, transportation, and other charges, for

[a] The estimates under this heading have been revised from the original figures given by the author to correspond with the latest data.—C. L. M.

47,000,000 barrels at $1 we have a cash valuation of $47,000,000 for the first and second qualities.

It is well within the limits of safety to estimate that one-fourth more apples would have been placed on the market had it not been for the codling moth. This one-fourth would be about 12,000,000 barrels, and would have no value except for cider or local sale at very low price. The average price for cider apples is about 30 cents, which price would yield a total of about $3,600,000 as the value of the windfalls, culls, and cider apples, while if they were average apples, at $1 net per barrel the value would be $12,000,000, showing an annual loss of about $8,400,000. The loss in home orchards, in which the percentage of loss is far greater than in the commercial orchards, is estimated at $3,000,000, giving a total annual loss of $11,400,000.

The loss in the country at large or any section of the country will vary with the size of the apple crop. In years of full crops the comparative injury is not so great as in years when the crop is small and the prices high.

FOOD HABITS.

This insect is essentially a feeder upon rosaceous fruits, and to them all of the injury is done.

FRUITS INFESTED.

The apple is by far the most infested fruit. It is the natural food of the codling moth, and under ordinary circumstances is the only fruit injured, save pears. It is quite safe to assume that the larvæ of the codling moth originally fed upon the leaves of the apple and that the habit of burrowing in the fruit is acquired. Much has been said and written as to the resistance by different varieties of apple to this insect. In Bulletin 35, new series, Division of Entomology, the writer gave a list of varieties and indicated the resistance. It is a notable fact that the summer varieties of apples are very attractive to the second generation of insects. Varieties which are fragrant, as the Pewaukee and Ortley (Bellflower), are always badly infested. As a general rule, one can say that the harder and less ripe late apples are not attacked to the same extent as those which are ripe and fragrant when the second generation enters.

It is impossible, from the nature of the case, to determine the exact ratio of resistance of the varieties. In one orchard one will find fruit of the Ben Davis variety least infested, while in another it will be the most infested. These differences are without doubt due to local conditions in the different orchards.

Pears are next in order of infestation. Under ordinary conditions they are not injured to any great extent. In the Pacific Northwest in badly infested localities the injury rarely reaches a total of 20 per cent. When remedial measures are used this is reduced to from 5 to 15 per cent. Several pear orchards have been noted which were located in neglected orchards in which there were few or no apples. The second generation of the insect seemed to concentrate its destructiveness on the pears, and in one case fully 80 per cent and in another about 50 per cent were injured. One fruit grower in Texas reports an injury of 50 per cent.

Crab apples are not usually so badly infested, but instances have been observed where they suffered fully as much.

Many records also show that peaches, prunes, plums, cherries, quinces, and apricots are infested by the codling moth, but under ordinary conditions their injury amounts to practically nothing. In cases where there is a lack of apples and the infestation is very abundant considerable damage results. There are records of 40 per cent injury to peaches where the trees were quite near an apple house in which infested fruit was stored.

NUT-FEEDING HABITS.

There are several European records of this insect in walnuts and oak galls. In 1887 Dr. Howard carefully sifted these reports, and concluded that the evidence was not sufficient to definitely prove that the insect ever feeds upon either walnuts or oak galls; and it was highly probable that the larvæ, if they were larvæ of the codling moth, went into the latter for the purpose of spinning their cocoons.

In 1895 Mr. Adkin exhibited a specimen of *C. pomonella* which was bred from a species of chestnut, and in 1896 gave details as to rearing this insect from walnuts, and offers the explanation that these nuts bear fleshy coats, or that the insect was originally a nut feeder. Theobald in 1896 wrote that in his investigations, extended over many years, he had never himself bred *Carpocapsa pomonella* from walnuts, but had found both *C. splendana* and *Plodia interpunctella*. Mr. West stated that he had also bred the insect from chestnut.

Dr. Riley in 1869 recorded that he had a specimen of a moth which had been bred from the sweetish pulp of a species of screw bean (*Strombocarpa monoica*) obtained from the Rocky Mountains. Professor Cockerell raises the question of the correctness of this record. In 1894 Professor Bruner reported that it is highly probable that the insect feeds in the seed buds of roses. In 1901 the writer carefully searched over many hundreds of these seed buds of roses near a badly infested orchard, and did not succeed in finding a single one that was in any way injured by the codling moth.

LEAF-FEEDING HABITS.

Professor Card in 1897 recorded that the young larvæ, especially in confinement, nibbled portions of the leaf. The writer has noticed many times leaves that had been eaten where he thought the work was done by this insect. Professor Cordley has succeeded in making some observations upon this leaf-feeding habit which are of great value. In a recent letter to the writer he details his experiences as follows:

It was found on June 4 that these eggs had hatched and nearly all of the larvæ were dead. Two of them, however, had fed upon the leaves, were yet alive, and had made some growth, notwithstanding the fact that the leaves had been taken from the tree nearly a month before and were therefore presumably not in the most palatable co -dition. Both larvæ were feeding upon the lower parenchyma of the leaf, and one had completely covered itself with a web holding pellets of frass. A recently hatched larva, mounted in balsam, measured 1.35 mm. in length; the larger of these two larvæ at this time measured 1.80 mm. in length and was proportionately stouter. Both were transferred to fresh leaves, upon which they fed until June 8, when one of them disappeared. The other continued to feed until June 11, when it too disappeared. However, I noticed a slight discoloration of the midrib of the leaf, near where this larva had been feeding, and on carefully opening it found the larva feeding as a miner, it having already excavated a tunnel about 15 mm. long. I then examined the other leaf, in which I found the larva that had disappeared three days before likewise feeding in the interior of the midrib. The larvæ were again transferred to fresh leaves, and by the following morning each had again disappeared within a midrib. Both larvæ continued to feed within the midribs until June 16, when one of them, on being transferred to a fresh leaf, refused to eat and soon died. The other, with occasional changes to new pastures, continued to thrive until June 25, when it was plump and active and apparently in the best of health and spirits. Unfortunately I was then absent from the laboratories for some days, and when I returned the larva was dead. I believe that with careful attention it could have been brought to maturity on a diet of leaves alone. When one considers that it lived and grew for more than three weeks upon leaves that had been severed from the tree sometimes for several days, and that it was apparently more thrifty between June 16 and 25 than in the earlier days of its existence, one must acknowledge that, while the proof is by no means positive, the indications are that codling moth larvæ may fully develop on a diet of perfectly fresh apple leaves without ever having tasted fruit. (See Pl. II, fig. 1.)

The writer has many times taken larvæ from apples and placed them upon leaves in cages and bottles. It was found that the larvæ would fasten the leaves together with silk and eat holes in them; but on account of lack of attention no larvæ were bred to maturity. The writer believes, and agrees with Professor Cordley in believing, that the larvæ with proper care can be brought to maturity on the leaf diet alone.

This question of the leaf-feeding habit of the codling moth is one of the most important questions in the life history of the insect, and should especially commend itself to entomologists for future investigation, since not only will it give us a very important biological fact, but it will also prove very definitely how spraying is effective against the insect.

It has often been recorded that larvæ gnaw cavities in rough rotten wood, bark, cloth, paper, and other places where they spin cocoons, and the bits of these substances incorporated in the cocoons. From observation it is evident that the larvæ do not eat any of these substances. When Paris green was placed under the bands and on the bark and in other places where the larvæ spin, it was found that none were killed, even when the poison was abundant, which tends to show that they do not eat of these substances.

PRIMITIVE FOOD HABITS.

Writers have indulged in speculation as to the primitive food habit of this insect. The other species of the genus are nut feeders, and Adkins expresses the opinion that this insect was originally such, and that the habit of eating apples was acquired.

The older writers have said that the insect was probably a leaf feeder. From the experience of Professor Cordley this view appears to be the more probable one.

WORK OF OTHER INSECTS.

There are many other insects which feed on apples whose work may be taken for that of the codling moth by those who are not familiar with the characteristics of the respective insects; but in all instances there are differences in the work and habits of the insects by which they may be easily distinguished.

The apple maggot (*Trypeta pomonella*).—This insect is quite injurious in the northeastern States, and its work in the apple is characterized by many winding tunnels through the fruit. The larva is footless, and has no distinct head, but tapers toward the front. This maggot is the early stage of one of the two-winged flies.

The peach twig-borer (*Anarsia lineatella*).—Injury to peaches and plums by this insect is often attributed to the codling moth, as its second generation feeds in the fruit. The larvæ are much darker red and much smaller than those of the codling moth, and the mature larva tapers toward either end (fig. 1).

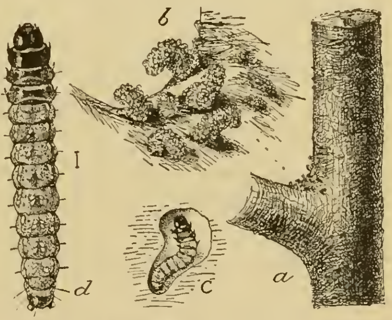


FIG. 1.—*Anarsia lineatella*: *a*, twig of peach, showing in crotch minute masses of chewed bark above larval chambers; *b*, latter much enlarged; *c*, a larval cell, with contained larva, much enlarged; *d*, dorsal view of young larva, more enlarged (from Marlatt).

The plum curculio (*Conotrachelus nenuphar*).—This insect often attacks apples, but can be easily distinguished by the crescent-shaped scar made in egg laying, by the small punctures caused by the adult in feeding, and by the fact that the larva, though it has a distinct head, is footless.

The Indian-meal moth (*Plodia interpunctella*).—This insect feeds upon edibles of nearly all kinds—meal, grain, seeds, nuts, dried fruits, etc. There is a common notion among some farmers that the larva of this insect is that of the codling moth, and the writer has often been told that the codling moth was introduced by its larvæ being imported in dried fruit. We have no reliable records of the codling moth having ever eaten dried fruit, and the Indian-meal moth is the principal insect that has been reared from such sources. The caterpillar is much smaller than that of the codling moth, and can be easily distinguished from it (fig. 2).

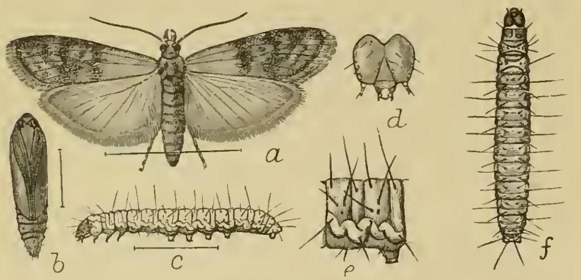


FIG. 2.—*Plodia interpunctella: a*, moth; *b*, chrysalis; *c*, caterpillar; *f*, same, dorsal view—somewhat enlarged; *d*, head, and *e*, first abdominal segment of caterpillar—more enlarged (from Chittenden).

The apple fruit-miner (*Argyresthia conjugella*).—The larva of this insect has been found attacking apples in British Columbia, and injuries which may have been caused by it have been noted in Washington, Idaho, and Montana. The larvæ are about one-fourth of an inch in length, are of a dirty white color, tinged with reddish when full grown, and taper at each end. The tunnels made in the fruit are numerous, and extend in all directions.

There are two species of Lepidoptera which do great damage to apples in Japan, which may sooner or later succeed in entering this country.

Apple fruit-borer (*Laverna herellera*).—This insect is said to have gained a foothold in British Columbia. The larvæ live only at the core of the fruit, injuring the seeds. When full grown they make a passage out, crawl or drop to the ground, and spin a white cocoon in the earth. They hibernate as pupæ, and there is only one generation each year. The species is shown in fig. 3, which also illustrates its manner of work.

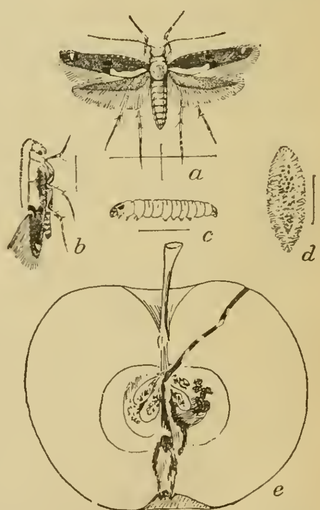


FIG. 3.—*Laverna herellera: a*, adult; *b*, same, side view; *c*, larva; *d*, cocoon; *e*, injured apple—all slightly enlarged except *e*, which is reduced (redrawn from Matsumura).

Pear fruit-borer (*Nephopteryx rubizonella.*)—It is stated that in Japan the pear crop is injured to the extent of 30 to 50 per cent each year by this insect. The eggs are laid in clusters on the twigs and leaves, the larva making its way thence to the nearby fruits, which it enters. The principal work is around the core of the pear. The larval stage lasts three weeks or more, and the pupal stage is passed within the fruit. The insect hibernates in the egg stage. The moth, larva, and pupa are illustrated by fig. 4.

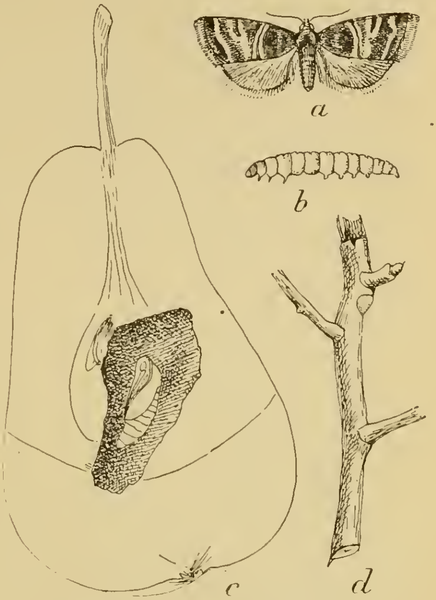


Fig. 4.—*Nephopteryx rubrizonella:* adult above, larva just beneath, egg mass on twig at right; damaged pear with pupa at left—all natural-size (redrawn from Matsumura).

Unknown caterpillar working on outer surface of apples.—Opportunity is taken of presenting the reproduction of a photograph of apples injured by an insect, which in its larval stage somewhat resembles the codling moth, but which we have as yet failed to rear and identify.

The injury was first brought to the attention of the Division of Entomology by Mr. D. W. Coquillett in October, 1901. The apples furnished were purchased in open market in the city of Washington. The injury appeared to be almost exclusively on the outer surface, consisting in the cutting away of the skin and disfigurement of the apples and considerably depreciating their value as salable articles (see Pl. II, fig. 2). In some cases holes entering the fruit to the depth of about one-fourth of an inch were found; in one apple to the depth of one-half inch. In November Dr. L. O. Howard also furnished specimens of apples showing injury by the same species. One of the larvæ spun up and formed a cocoon November 6. Unfortunately all the larvæ died without our securing the moths. The following brief description of the larva was made:

Reddish flesh-colored, head dark brown, central portion of face whitish and transparent, with two black spots; cervical shield transparent, except for caudal margin Three setæ on the pre-spiracular tubercle. Length, five-eighths of an inch when spinning cocoon.

It will be noted that the injury illustrated and described is quite different from that mentioned and figured on pages 87 and 88 of Bulletin No. 10 (new series) of the Division of Entomology.

LIFE HISTORY.

Of all insects the codling moth has the largest number of biographers. It has been studied in nearly every country in the world and in all climates in which it exists. The early accounts were always more or less vague and inexact and gave rise to many false ideas. Gradually these points were worked out until to-day we can say that the life history of the insect is as well if not better known than that of any other. Yet, with all the knowledge we have of it, there remain several important points to be determined by future work.

It is a fundamental principle of economic entomology that in order to successfully combat an insect the life history of that insect must be given a keen, searching study. With few exceptions these studies reveal some point in the life of the insect at which it is vulnerable to preventive or remedial measures. Without this knowledge efforts are wasted and in some cases are a positive aid to the insects. It can not be too strongly urged that each fruit grower make himself familiar with the life history of the codling moth from personal observation, for by doing so he is placed in a position to understand the reasons for measures of control and to exercise his ingenuity in applying the same to his own orchard.

The ease with which collections can be made in the larval stage and the accessibility of literature pertaining to it should specially commend this insect to teachers as a subject for nature-study lessons.

In the present studies upon this insect particular care has been taken to keep the different stages under observation in exactly the same conditions of temperature, moisture, and light as were present in the orchard in which the cages were located, and as a result the writer is able to present some definite data in regard to the effect of temperature upon the length of the stages of the insect under normal conditions.

As in other lepidopterous insects, the life of the codling moth is divided into four distinct stages—egg, larva, pupa, and adult. In the winter and early spring the larvæ may be found in their cocoons in various places, as in cracks and holes in the trees. Later the larva transforms into a pupa, and this in turn changes to a moth, which in turn lays eggs.

THE EGG.

Since the time of Roesel many authors have mentioned the egg of the codling moth and stated where it was laid, but it was as late as 1893 that it was first accurately described and figured. In 1874 Mr. W. H. Hurlbut described the egg as being about one-eighth of an inch in length and nearly white. Riley described it as being very small and of a yellow color. Messrs. A. J. Cook, Koebele, Weir, and others undoubtedly saw the eggs, but Cook in 1881 and Miss M. Walton doubtless saw the eggs of some other insect.

In 1893 Professor Washburn gave an accurate description of the egg, with the first figure of it. This figure shows a well-formed embryo inside, but the network of ridges near the center is much too open.

Slingerland in 1896 and Card in 1897 distinguished the eggs and made many observations which added materially to our knowledge of this stage. In his 1898 bulletin Slingerland publishes many excellent photographs and descriptions which caused the eggs to be familiar objects. Influenced by Slingerland's and Card's work, Aldrich, Cordley, Gillette, and others have from time to time added to the sum of our knowledge of this stage of the insect. It is remarkable that, in spite of the many studies of its life history, the egg escaped notice for so long and when seen was not described and figured until a comparatively late date.

The egg is a flat, somewhat oval-shaped object with a flange around it. It varies in size from 0.96 to 1 by 1.17 to 1.32 mm. Commonly speaking, it is about the size of a pin head. The surface is covered with a network of ridges which are much closer together toward the central portion than around the edge. The color depends upon the age of the embryo; as when the egg is first laid it is of a pearly white color, sometimes with a decided yellowish tinge; later it is darker on account of the red ring. The eggs are always glued to the apple or leaf and one often finds shells which remain for some time after the larva has hatched. The reflection of light from the egg is of the greatest aid in finding them, and they have often been described as reflecting the light like "trout scales." (See Pl. III.)

PLACES WHERE LAID.

Having never seen the egg, the early writers were forced to guess as to where it was laid. They stated that the eggs were laid either in the stem end or in or about the calyx end of the apple. These views were held because of the position of the entrance holes of the larvæ. These ideas were published again and again for over a century, and American writers copied them until about 1897, when, by a series of observations, it was proved that they were incorrect. In 1889 Koebele and Weir stated that the eggs are laid at any point upon the apple and are "as a rule laid elsewhere than within the calyx." Washburn in 1892 found that the eggs were "placed on both sides and the top of the fruit." In the spring of 1896 Slingerland found that in confinement the moths laid eggs on the sides of the cages, on leaves, and on bark. Card in 1897 found that the eggs were laid almost exclusively upon the upper surface of the leaves, and in 1897 only 2 eggs were observed in the field. In a recent letter Professor Cordley states that out of 15 eggs laid in confinement the greater number were on the fruit, and that he has never seen an egg of the first generation upon the fruit in the field.

The apparent contradictions of these observations may be accounted for by the fact that they were made upon the eggs of different generations of the insect. The writer has found that in Idaho but few of the eggs of the first generation are laid upon the fruit. In one limb cage a moth laid 21 eggs, only one of which was upon the fruit; and in another cage 24 eggs were laid and only 2 were upon the fruit. Very few eggs of this generation were observed to have been laid upon the fruit in the field. Professor Cordley suggests that the moth does not lay eggs upon the young fruit on account of the pubescence, which is afterwards lost. This is most probably the cause. In the field one can often find fruit, surrounded by leaves, upon which there are no eggs, while several may be found upon the upper surface of the leaves.

A good percentage of the eggs of the second generation are laid upon the fruit in the field. When the fruit is scarce a larger number is found upon the leaves. The average of several rough countings in the field gave an average of about 50 per cent laid upon the fruit. Breeding records show that out of 175 eggs of this generation in limb cages on inclosed branches and fruit there were 71 eggs upon the leaves, 95 upon the fruit, and 9 upon the twigs. Very few eggs are laid upon the underside of the leaves, and it seems that the moth much prefers a smooth surface upon which to oviposit.

We may therefore conclude that the eggs of the first generation are for the most part laid upon the leaves, while the majority of those of the second brood may be found upon the fruit.

WHEN THE EGGS ARE LAID.

Various writers have stated that the eggs were laid at night. Cooley records that he observed a moth depositing eggs at about sunset. The writer's observations show that the oviposition for the most part is accomplished in the late afternoon or early evening, while a single observation shows an egg to have been laid sometime between 9 and 12 o'clock in the morning.

THE NUMBER OF EGGS LAID BY ONE FEMALE.

There is probably less definite data on this point than on any other in the life history of the insect. Many guesses have been ventured as to the number of eggs that one female will lay, varying from 12 to 300 and over. LeBaron found from 40 to 60 eggs, with an average of 50, in various stages of development, in the ovaries of the female at the time of emergence. He adds that if all the undeveloped eggs came to maturity this number must be increased. Matthew Cooke said that he had a vial in his possession in which a codling moth laid 85 eggs. The writer was unable to secure eggs in this way. In only two instances has the writer made definite observations on the number of eggs laid by a single female moth. Two pairs of moths were secured in copula and placed in separate limb cages. In one cage 21 eggs were found, but as the moth escaped the observation was inconclusive. In the other cage 25 eggs were laid, but a spider put an end to the experiment before a definite conclusion was reached. In view of these incomplete observations the writer can only venture an opinion that the maximum number of eggs laid by one moth is about 50, with the average between 30 and 40, which is comparable to definite records of other insects of this family.

THE EGG-LAYING PERIOD.

Upon dissection of the ovaries of the female of the codling moth the eggs are found in various stages of development. It is also noted that eggs are laid when they are in different stages of maturity. From these facts we may conclude that the egg-laying period extends over some time. Various authors have given the length of time from the emergence of the moth to the beginning of the laying of the eggs as from 48 hours to 6 or 8 days. Professor Gillette gives the time as about 5 days. The various records of writers show that this time varies from 2 to 7 days, with an average of from 4 to 5 days.

DURATION OF EGG STAGE.

In 1746 Roesel stated that the egg hatched in 8 days. Recent authors give the length of the stage as follows: LeBaron, one week; Washburn, 5 to 10 days; Riley, 4 to 10 days; Slingerland, one week; Card, 8 to 10 days; and Professor Gillette, 6 to 8 days in his laboratory, with a known temperature, and in the orchard one day longer. Cooley records 12 days as the length of the stage of one egg.

The results of observations upon 164 eggs and observations of Professor Cordley are given in Table I, with the total and average effective temperature to which the eggs were subjected.

TABLE I.—*Duration of egg stage of codling moth.*

Date laid.	Number laid.	Date hatched.	Number hatched.	Period of incubation.	Total effective temperature.	Average effective temperature.
1902.		1902.		*Days.*	° *F.*	° *F.*
May 30	21	June 11	1	12	228	19
		June 12	3	13	253	19
		June 13	17	14	347	24.7
Aug. 11	1					
Aug. 12	7	Aug. 21	3	9	206	23
		Aug. 23	5	12	266	22
Aug. 16	6	Aug. 25	6	9	217	24
Aug. 26	9	Sept. 5	6	11	247	22
		Sept. 6	3	12	276	23

TABLE I.—*Duration of egg stage of codling moth*—Continued.

Date laid.	Number laid.	Date hatched.	Number hatched.	Period of incubation.	Total effective temperature.	Average effective temperature.
1902.		1902.		*Days.*	° *F.*	° *F.*
Aug. 27	27	Sept. 5	8	9	278	30
		Sept. 6	14	10	307	27
		Sept. 8	2	12	360	27
Aug. 28	61	Sept. 8	3	11	269	24
		Sept. 9	4	12	295	24
		Sept. 12	32	15	364	24
		Sept. 15	2	18	428	24
Do	14	Sept. 9	1	12	216	18
		Sept. 6	11	9	269	29
		Sept. 15	1	18	428	24
Aug. 29	40	Sept. 8	3	10	254	25
		Sept. 9	5	11	286	25
		Sept. 12	3	14	349	24
	187	....	164	243	....	....
CORDLEY.						
May 7	8	June 1	....	24	298	12
Do	15	May 12	....	5	285	47

The results under normal orchard temperature give the length of the stage from 9 to 18 days, with a weighted average of 11 days. This average is longer than has been given by other authors, which may be accounted for by the fact that it is the usual custom to keep the eggs in laboratories rather than under normal orchard conditions, and that the times of the laying of the eggs were estimated.

HATCHING OF THE EGG.

Recent authors are quite well agreed as to how the larva breaks or eats its way out of the shell. Professor Slingerland was most probably the first to observe this operation. He states that the larva came out of the egg near the edge at one end through an irregular crack in the shell. (Pl. III, *es*.) The writer has never observed this emergence, but upon examining many egg shells an irregular crack was always found which was almost always at one end of the shell.

CHANGES DURING INCUBATION.

When laid the egg is of a translucent pearly color, often with a yellowish tinge. Observations upon 88 eggs show that from 2 to 5 days with a weighted average of 3 days after being laid a red ring makes its appearance. This ring appears gradually at first whitish, then yellowish, and later quite a brilliant red. By observations upon 56 eggs it was found that in from 7 to 10 days, with a weighted average of 8.4 days after being laid, the egg loses the ring and in its place the larva can be seen, the "black spot," which consists of the head and cervical shield, being the most conspicuous part.

Professor Gillette states that his assistant, Mr. E. P. Taylor, found the red ring to appear in from 2 to 3 days after laying and the black spot appeared 2 to 3 days later. This shorter average may be accounted for by the fact that these eggs were kept at a higher temperature than normal.

METHODS OF OBTAINING EGGS.

There are two ways of obtaining eggs for study. The first is to collect them in the field and place them under observation in cages. There is a serious objection to this method, as there is no way of knowing the age of the eggs. The second method, that of confining larvæ and pupæ and allowing the moths to emerge, is far more satisfactory. If these moths are placed in a cage over a limb of a tree, one will find eggs in abundance in a day or two. One is sometimes fortunate enough to find moths in copula, and in that event they should be placed in a separate cage. By determination of sex of the various moths much more valuable data can be secured. Care must be taken that too many eggs are not laid in one cage, as in that event it is difficult to keep accurate notes.

These limb cages are bags made of mosquito netting of finer mesh than the ordinary netting. By this method the leaves and fruit are always fresh and the conditions are exactly the same as in the orchard.

INFLUENCE OF TEMPERATURE UPON THE LENGTH OF THE EGG STAGE.

It has often been stated that a higher temperature caused the eggs to hatch in a shorter time, but only a few definite observations have been recorded. The temperature used in these calculations is the effective temperature, which is obtained by subtracting 43° from the mean daily temperature as recorded by the United States Weather Bureau station at Boise, Idaho.

Professor Gillette gives $6\frac{1}{2}$ days as the length of this stage at a temperature of from 68° to 70° F. and 6 days as the time in a greenhouse where the temperature was 110° F. at midday. In Table I the total and average effective temperature is given from the time the eggs were laid until they were hatched. These data are arranged according to the temperature in Table II.

TABLE II.—*Effective temperature and period of incubation.*

Average effective temperature.	Total effective temperature.	Length of stage.	Average effective temperature.	Total effective temperature.	Length of stage.	Average effective temperature.	Total effective temperature.	Length of stage.
° F.	*° F.*	*Days.*	*° F.*	*° F.*	*Days.*	*° F.*	*° F.*	*Days.*
12	298	24	24	217	9	25	254	10
18	216	12	24	269	11	25	280	11
19	228	12	24	295	12	27	307	10
19	253	13	24	349	14	27	366	12
22	247	11	24	364	15	29	269	9
22	266	12	24	428	18	30	278	9
23	206	9	24	428	18	47	285	5
23	276	12	25	247	14			

Average total effective temperature, 302° *F.*

This table is not complete, in that not sufficient observations were made at lower and higher temperatures; and it is dangerous to make any extended conclusions therefrom. A study of the table shows:

First. Under a low temperature the length of this stage is longer than at high temperatures.

Second. The total temperature varies from 206° to 428° F., and the average is 302°; and in general eggs have to be subjected to this amount of heat before they hatch, whether it be for a longer or a shorter period of time.

Third. The eggs are not at the same state of maturity at the time of oviposition, as at 24° we have from 9 to 18 days as the length of stage.

Fourth. Under normal field conditions a small difference in temperature causes but little change in the length of the stage.

MORTALITY AMONG THE EGGS.

Various observers, among them Washburn, Goethe, Card, Slingerland, and Cordley, have found that many eggs of this insect did not hatch. There is little doubt that at least one of these writers mistook eggs from which the larvæ had hatched for dead eggs. The writer has noted that many eggs became hard and dry, while in others the contents changed to a dark brown color. These changes may have been caused by infertility, parasites, or the excessively hot sun. The mortality as shown by our breeding-cage records is by no means so great as the writer had supposed. The eggs, however, were more or less protected.

THE LARVAL STAGE.

Considering the codling moth in its economic relations, it may be said that the larval is the most important stage of the insect. Not only is it distributed, and does all of its damage in this stage, but it is more amenable to remedial measures.

At the time of hatching the young larva is from one-twentieth to one-sixteenth of an inch in length, of a semi-transparent whitish or yellowish color, with large, shiny, black head, and dark cervical and anal shields. The body shows regularly arranged spots with short hairs or setæ.

If hatched upon the apple the young larva seeks a place to enter, which is in general some irregularity upon the apple or at the calyx. Slingerland, Card, and Cordley have made many excellent observations upon the place of entrance. When hatched upon the leaves they may not find an apple for some time, and subsist by eating small portions of the leaves. In confinement this often occurs, but it has never been determined accurately how often it takes place in the field. The writer has time and again noted these spots on the leaves in the field, and has noted also that larvæ hatched on leaves would have to go from

10 to 20 feet before they could find an apple. Card notes that comparatively few eat of the leaves in the open, but from such observations as we have the writer is strongly of the opinion that it is quite a general habit.

DESCRIPTION OF FULL-GROWN LARVA.

When full grown the larvæ are about three-quarters of an inch in length, and their heads measure from 1.54 to 1.76 mm. across the broadest portion. The majority are of a pinkish or flesh color, which is much lighter or absent on the under side. It was thought for a long time that the pink color was due to the larva having fed on some particular varieties of apple; but the white and pink larvæ have often been found feeding on fruit from the same tree. The head is brown in color, with darker markings, while the cervical and anal shields are much lighter. The spots in which the minute short hairs are situated are but little darker than the body wall, but can be easily distinguished with a hand lens. The mandibles are the most noticeable feature of the mouth parts. Beneath the under lip is the spinneret, from which the silken thread is drawn. The larva has eight pairs of legs. The first three pairs, or true legs, are situated on the thorax, and are three jointed. Later these form the legs of the adult insect. The five pairs of fleshy abdominal legs, or prolegs, disappear in the pupal stage of the insect. The first four pairs of legs are armed with circles of hooks, while the hooks on the two pairs at the end of the body are arranged in a semicircle. The spiracles or breathing apertures of the larva are arranged on either side on separate segments of the body. (Pl.V, fig. 1.)

ENTERING THE FRUIT.

The usual place of entrance of the first generation is by way of the calyx. The larvæ either squeeze their way into the calyx between the lobes or tunnel into the cavity at the base of the lobes. A scar, the stem, or a place where fruits touch is often selected as the place of entrance. In 1900 the writer observed an egg shell with a larval entrance hole at the edge and partly under the shell. In view of later observations it is more probable that some larva crawling around found this obstruction and entered, rather than that the larva entered the fruit directly from the shell.

The second generation for the most part enter on the sides of the fruit. The larva crawls rapidly about the apple, seeking a place for entrance. A scar or roughness is a favorite place, as the jaws slip on the smooth skin. In its wanderings the larva spins a silken thread and finally makes a web over the surface of the apple. With this as a foothold it is able to make some impression upon the skin, which is bitten out in chips and dropped into the web. Later, when it is partly covered, the larva backs out of the burrow and brings pieces out with it. This is repeated until it is entirely within the burrow, when it turns around and spins a silken net over the hole, in which may be incorporated several pieces of the fruit. (Pl. IV, fig. 1.)

Slingerland, Card, and Cordley have also noted these larvæ enter, and the observations made by the writer agree entirely with theirs. One of the essential points noted is that while entering none of the larvæ seem to eat any of the fruit until well within the burrow, and it most probably gets some of the poison applied in spraying when it attempts to pierce the skin. The writer has observed numerous larger larvæ, and is quite positive that they do not eat any of the fruit while they are entering.

PLACES OF ENTRANCE.

The places of entrance of the successive broods are quite different. Various authors have stated that from 60 to 80 per cent of the larvæ of the first generation enter the fruit by the calyx. In 1901 several countings gave an average of 83 per cent, with a minimum of 79 per cent. In 1902 much more extensive countings gave a maximum of 93 per cent, a minimum of 50 per cent, and an average of 81 per cent. (Table III.) Less than one-half of 1 per cent enter by the stem end, while the larger remaining percentage enter the side, especially where fruits touch.

The majority of the second generation enter the side of the fruit. A few counts in 1901 showed that the greater part of the larvæ entered the side, and a few cases showed that from 90 to 100 per cent had entered at that place. Countings on 1,478 apples in September, 1902, on both sprayed and unsprayed trees, are given in Table III.

Table III.—*Percentage of first generation entering calyx.*

SPRAYED TREES.

Orchard.	Variety.	Date.	Stem.	Side.	Calyx.	Total.	Per cent in calyx.
McPherson	Jonathan	July 18	0	2	2	23	91.3
Do	Ben Davis	July 22	0	2	28	30	93.3
D. Geckeler	do	July 19	0	8	8	16	·50
Total			0	12	38	69	82.6

UNSPRAYED TREES.

Orchard.	Variety.	Date.	Stem.	Side.	Calyx.	Total.	Per cent in calyx.
J. D. Gray		July 17	2	31	67	100	67
Do		July 19	0	38	62	100	62
Do		July 21	0	4	23	27	85.1
Do		July 25	0	7	23	30	76.6
Dr. Collister	Wealthy	July 22	0	21	236	257	91.8
McClellan		July 31	0	2	13	15	86.6
Total			2	103	424	529	80.1

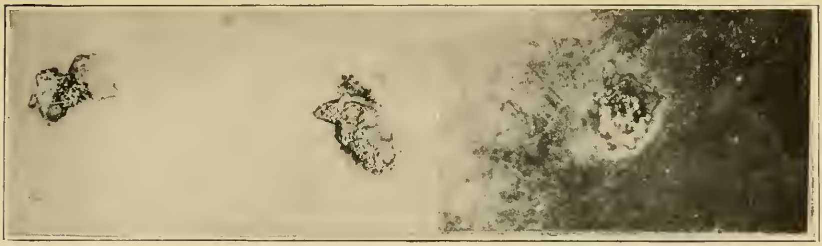


FIG. 1.—ENTRANCE HOLES OF LARVÆ OF THE SECOND GENERATION.

FIG. 2.—VIEW IN ORCHARD OF HON. EDGAR WILSON, SHOWING LOCATION OF APPLE HOUSE IN RELATION TO ORCHARD.

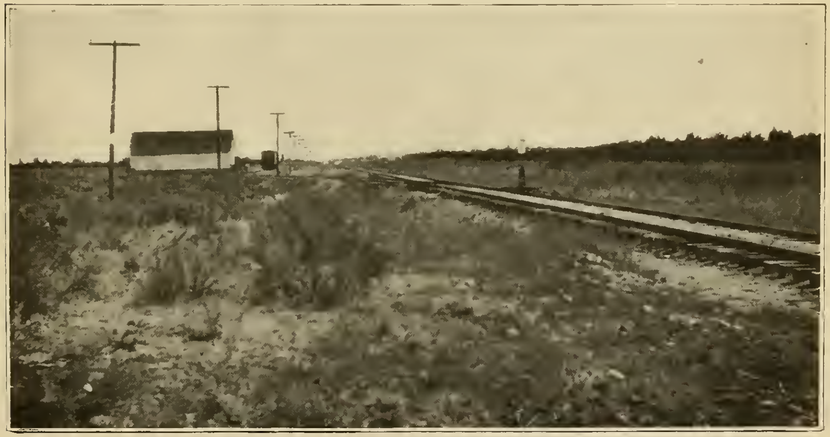


FIG. 3.—ANOTHER VIEW IN ORCHARD OF HON. EDGAR WILSON, SHOWING LOCATION OF APPLE HOUSE WITH REFERENCE TO THE RAILROAD.

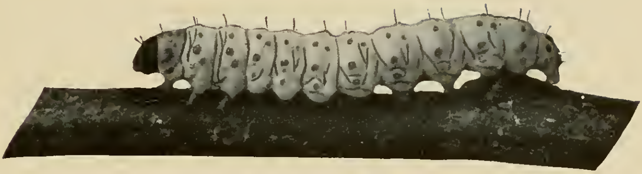


FIG. 1.—CODLING MOTH LARVA (ENLARGED ABOUT 3 TIMES).

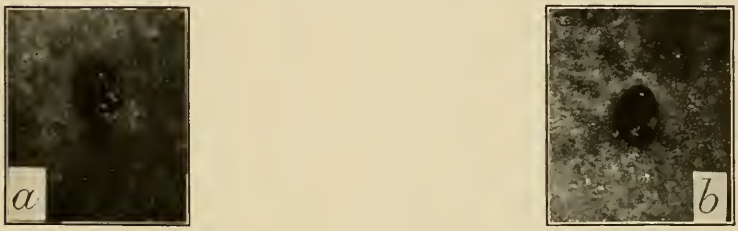


FIG. 2.—THE WORMHOLE OR EXIT HOLE OF THE APPLE (ENLARGED).

FIG. 3.—A WORMY APPLE, SHOWING THE FAMILIAR MASS OF BROWN PARTICLES THROWN OUT AT THE BLOSSOM END BY THE YOUNG LARVÆ (FROM SLINGERLAND).

Places of entrance of the second generation.

UNSPRAYED TREES.

Stem.	Side.	Calyx.	Total.	Per cent calyx.
4	66	57	127	44.4
5	74	31	110	28.1
12	104	76	192	39.5
4	97	41	142	28.8
1	20	12	33	36.3
1	58	14	73	19.1
27	419	231	677	[a] 26.1

SPRAYED TREES.

1	56	28	85	32
11	204	21	236	8.8
0	37	36	73	49.3
0	41	14	55	25.4
0	32	9	41	21.9
0	50	34	84	40.4
0	19	18	37	48.7
0	50	21	71	29.5
1	11	12	24	50
0	32	16	48	33.5
0	22	7	29	24.1
0	9	9	18	50
13	563	225	801	[a] 28

[a] Average.

The tables of the places of entrance of the first generation on sprayed trees show some interesting facts, and it is to be deplored that the records are not more extensive.

No definite data was secured in regard to what percentage of the larvæ enter the sides where fruits are touching. In badly infested orchards it is almost impossible to find such fruits into which a larva has not entered. It would be safe to estimate that fully 50 per cent, if not more, of the larvæ entering at the sides enter where the fruits touch.

Immediately after entering the calyx cavity the larva takes its first meal. We have a lack of data as to exactly what is eaten, but most probably the larva acts as it does when the side is entered. After spinning the web over the hole the larva, when it enters the side, eats out a cavity under the skin and throws out but little castings. This mine is eaten outward from the point of entrance, and in from 3 to 5 days the larva begins its tunnel toward the center of the fruit, reaching that point when about one-quarter grown and about a week old.

While at the surface, or while tunneling toward the center of the apple, the larva pushes its excrement and frass through the entrance hole. Later the entrance hole, especially at the calyx, is enlarged, and a considerable amount of frass is thrown out, which characterizes the infested fruit (Pl. V, fig. 3). When a considerable cavity has been made in the interior of the apple the excrement is bound together with silk. Upon reaching the central portion of the fruit the larva eats out an irregular cavity about the core, and seems especially partial to the seeds.

The insects pass through five larval stages, and increase in size by shedding their skins four times to allow for growth. The width of the head of the larva in these different stages averages as follows: First stage, 0.38 mm.; second stage, 0.55 mm.; third stage, 0.78 mm.; fourth stage, 1.12 mm.; fifth stage, 1.6 mm. When in the latter part of the first stage and the second part of the third stage the larvæ are whitish in color, but with the cervical and anal shields black, and with blackish spots around the setæ. In the later stages the shields become brown, and the spots around the hairs are usually indistinct, especially in the pinkish larvæ.

TIME SPENT IN THE FRUIT.

Very few definite observations have been made in regard to the time the larva spends inside the fruit. Le Baron gave the time as four weeks; Riley, 25 to 30 days; Slingerland, 20 to 30 days; Card, 10 to 14 days; and Cordley, 16 to 24 days. From the nature of the case it is most difficult to get exact data on this point, as there are many accidents which may prove fatal to the experiment. On only 5 larvæ was the writer able to obtain results definite enough to use with any degree of confidence. One of these larvæ remained in the apple 14 days, two 18 days, one 21 days, and another 26 days. Professor Gillette kindly furnishes some unpublished data on this point, in which he finds larvæ to have stayed in the fruits 12, 18, 20, and 24 days, respectively, with an average of 19 days. The average of all these observations is about 20 days.

PREPARATIONS FOR LEAVING THE FRUIT.

When about full grown the larva makes a passageway to the outside of the fruit. This is usually made toward the side of the apple, in a different direction from that from the entrance hole. Rarely does the exit passage follow along or consist of the enlarged entrance passage. Before the larva has passed outside the outer portion of the passage is filled with a block of frass (Pl. V, fig. 2, *a*), or a cap of silk is spun over the hole.

LEAVING THE FRUIT.

When ready to leave the fruit the larva pushes out this block or tears away the cap of silk, crawls out on the surface of the apple, and immediately seeks a place in which to spin a cocoon. (Pl. V, fig. 2, *b*.) If the apple is upon the tree the larvæ will, in by far the greater number of cases, crawl from the apple to the twig, from there to the branch, and thence down upon the trunk of the tree. Another method, which is comparatively rare, is that in which the larva lets itself down to the ground by means of a silken thread. This may be on account of the fact that the larvæ sometimes drop accidentally and use the silken thread to support themselves. It is not uncommon to find these threads extending through the branches of trees which are badly infested with the codling moth.

Professor Gillette finds that 85 per cent of the larvæ enter the bands during the night, and the remaining 15 per cent during the day, in August. Observations of the writer show that in the summer the larger percentage enter the bands from 6 p. m. to about 11 p. m., at Boise, Idaho. After 11 p. m. it is usually so cool that there is but little activity. In September the conditions as given by Gillette are about reversed. The nights are cold, and the larvæ are active only during the warmer parts of the day, at which times they enter the bands.

If the apple has fallen to the ground the larva simply crawls into a convenient place and spins its cocoon. After leaving the fruit the larva is unprotected, and does not consume much time in finding a place to start its cocoon.

PLACES OF SPINNING COCOONS.

In orchards the cocoons are normally found in cracks or holes in branches or trunks of the trees, under scales of rough bark, and in the rough bark on the main branches of the trees. When the trunk of a tree is smooth the cocoons are often found under bits of bark and in the earth about the foot of the trees. Cocoons are found under anything on the tree or leaning against it, as bands placed around the trunk, rags tied around the limbs, or boards and sticks leaning against the tree. When much fruit has fallen the larvæ seem to have a greater range in spinning cocoons, often placing them among clods of earth, beneath paper or any other rubbish on the ground, in the cracks and rough bark of adjacent trees, in piles of wood or lumber, in fence posts, and under the pickets of fences. In piles of fruit in the orchards the cocoons are normally found placed among the apples; in orchards where the trunks and branches of the trees are smooth, the cocoons are often found in the cracks of the earth about the foot of the trees, and when fruit is lying on the ground they have been found among the clods of earth by Cordley and McPherson. Cordley published a photograph showing a cocoon on a clod of earth. In the writer's experience two cases have been found in which a cocoon was spun inside of wormy fruit. It was impossible to tell whether or not the larvæ which had spun these cocoons were those which had done the injury to the fruit. In packing houses it is quite common to find the larvæ in cracks of the floor, walls, and roof, in piles of lumber or boxes, and in the angles and cracks of boxes or barrels used for handling the fruit. The larva usually gnaws out a cavity in which to spin its cocoon. These cavities are often found in the interior of rotten trees, stumps, and fence posts, with passages excavated into these rotten pieces of wood from 2 to 4 inches. In the spring cocoons can be found only in the more secure places, those spun in more exposed places having been eaten by their enemies. (See Pl. VIII.)

DESCRIPTION OF THE COCOON.

The cocoon is composed of silk, which is the product of the pair of silk glands common in many orders of insects. These glands are situated on either side of the alimentary canal, and consist of three parts, each of which has a separate function. The cephalic portions unite to form a single tube in the head of the insect, which extends to the external opening or spinneret. The spinneret is a chitinous projection on the under side of the labium or lower lip. Throughout its life the larva makes use of this silk in various ways.

When a suitable place has been selected for the spinning of a cocoon the larva begins to weave about itself this single thread of silk. The exterior outline of the cocoon conforms to that of the cavity or crack in which it is placed. While spinning the larva is bent upon itself and decreases considerably in size. When the cocoon is completed, which takes usually about one day, the larva straightens out and contracts in length. While tne exterior of the cocoon may be rough, the interior is always smooth and oval in shape. At completion of the spinning of the cocoon the alimentary canal, silk glands, and other organs peculiar to the larva begin to disintegrate.

In from 1 to 19 days, with an average of about 6 days, the larval skin is shed and the insect becomes a pupa. The cast larval skin can always be found at the caudal end of the body, shriveled into a rounded mass.

Various authors have noted that when the cocoon of the codling moth is torn or cut open, it is immediately repaired by the larva. Professor Slingerland states that the damage is repaired in winter. He has also had a larva spin two or three complete cocoons after having been removed very early in the spring from the one in which it had hibernated. The writer had one spin two new cocoons during the summer. Professor Gillette notes that in Colorado the larvæ leaving the cocoons in the early spring ieave those in which they have hibernated and seek other places in which to spin new ones and pupate. He reports that under 10 bands placed on the trees in the early spring 6 larvæ which were spinning new cocoons were taken.

Various reasons might be assigned for this habit of the insect. It might be that the cocoons are too deep in the wood of the trunk of the tree for the moth to emerge without materially injuring itself, or it may be that the larva on becoming active in the spring finds itself in a wet place, and, for either of these or some other reason, migrates to a better place and spins itself a new cocoon.

One of Professor Gillette's correspondents reports that he found 53 larvæ under 295 bands in two weeks. Another reports 307 larvæ April 2 and 409 April 17 from 2,500 bands. Gillette thinks that the number caught under these bands is too small to be of any great value as a remedial measure.

DURATION OF THE STAGES IN THE COCOON.

On account of the direct influence of this question upon the system of banding, particular care was taken to ascertain the duration of the cocoon stage, and especially the minimum time. The older writers gave estimates of this time with but little definite data. Riley gave from 15 to 21 days; Washburn, 3 weeks; Slingerland, 2 to 3 weeks, and Aldrich about 1 week. Professor Gillette gives records of complete experiments upon this point. In 1900 observations made for him upon 104 larvæ gave a minimum of 12 days, a maximum of 29 days, with an average of 20 days. Other experiments directed by the same writer in 1901 on 76 larvæ resulted in finding the minimum to be 3 days; maximum, 23 days, and average 16¾ days. In 1900 the writer found that in 7 cages the shortest time varied between 12 and 15 days, with an average minimum of about 14 days. In 1902 a large series of breeding experiments were carried out, the results of which are incorporated in the following table:

Table IV.—*Duration of life of the codling moth inside the cocoon.*

Date of entering band.	Number of larvæ.	Date moths emerged.	Number of moths.	Time.	Total effective temperature.	Average effective temperature.
1902.		1902.		*Days.*	° F.	° F.
June 29	16	July 19	2	20	433	21
		July 21	2	22	505	23
		July 22	2	23	543	24
July 14	35	July 30	1	16	494	31
		July 31	4	17	528	31
		Aug. 1	5	18	566	31
		Aug. 6	1	23	722	31
July 22		Aug. 9	2	18	583	32
		Aug. 11	1	20	645	32
		Aug. 29	1	38	1,115	29
		Sept. 1	6	41	1,170	29
		Sept. 5	2	45	1,284	29
		Sept. 9	2	49	1,392	28
July 29		Aug. 9	3	11	362	33
		Aug. 11	3	13	424	33
		Aug. 12	3	14	455	32
		Aug. 13	6	15	481	32
		Aug. 15	5	17	541	32
		Aug. 16	2	18	566	31
		Aug. 18	5	20	600	30
		Aug. 19	2	21	615	29
		Aug. 20	1	22	633	29
		Aug. 21	5	23	661	29
		Aug. 22	5	24	693	29
		Aug. 25	2	27	783	29
		Sept. 9	1	42	1,171	28
July 31	11	Aug. 18	2	18	535	30
		Aug. 19	1	19	550	29
		Aug. 20	1	20	553	28
		Aug. 21	1	21	581	28
		Aug. 23	3	23	641	28
Aug. 6		Aug. 18	1	12	209	17
		Aug. 19	1	13	224	17
		Aug. 21	3	15	270	18
		Aug. 22	4	16	302	19
		Aug. 23	3	17	330	19

TABLE IV.—*Duration of life of the codling moth inside the cocoon*—Continued.

Date of entering band.	Number of larvæ.	Date moths emerged.	Number of moths.	Time.	Total temperature.	Average temperature.
1902.		1902.		*Days.*	°	°
Aug. 6		Aug. 25	10	19	392	21
		Aug. 26	7	20	425	21
		Aug, 27	12	21	456	22
		Aug. 28	11	22	485	22
		Aug. 29	5	23	503	22
		Aug. 30	3	24	519	22
		Sept. 1	7	26	558	21
Aug. 13	8	....do...	1	19	468	25
		Sept. 8	3	26	674	26
Aug. 15	26	....do...	9	24	604	25
Aug. 20	28	Sept. 12	5	23	607	26
Aug. 22	25	....do...	2	21	547	26
		Sept. 17	1	26	633	24

The number of larvæ used was 170, and the stage varied from 11 to 49 days, with a weighted average of 22 days. This average is somewhat longer than that secured by other observers, and may be partly accounted for by the lateness of the season.

The principal point to be clearly shown is the length of the minimum stage, which these experiments show to be not less than 10 to 12 days.

The time spent in the cocoon by the hibernating larvæ varies considerably, but usually lasts about eight months. If the larvæ are taken inside and kept where the temperature is higher, moths will sometimes emerge in January or February.

INFLUENCE OF TEMPERATURE UPON THE DURATION OF THE STAGE.

Various authors have stated at various times that this stage might be considerably lengthened or shortened by temperature. Table V shows a preceding table arranged according to the effective temperatures and the lengths of time.

TABLE V.—*Effective temperature and length of cocoon stage of codling moth.*

Average temperature.	Total temperature.	Days.	Average temperature.	Total temperature.	Days.	Average temperature.	Total temperature.	Days.
° F.	° F.		° F.	° F.		° F.	° F.	
17	209	12	25	604	24	29	1,284	45
	224	13	26	547	21	30	535	18
18	270	15		607	23		600	20
19	302	16		674	26	31	494	16
	330	17	28	553	20		528	17
21	392	19		581	21		566	18
	425	20		641	23		566	18
	433	20		1,171	42		722	23
	558	26		1,392	49	32	481	15
22	456	21	29	550	19		541	17
	485	22		615	21		583	18
	503	23		633	22		645	20
	519	24		661	23		455	14
23	505	22		693	24	33	362	11
24	543	23		783	27		424	13
	633	26		1,115	38			
25	468	19		1,170	41			

From the table we find that the minimum total temperature is 209°, the maximum 1,392°, and the average 592°. The evidence given by this table is insufficient to warrant any definite conclusions. It is quite evident that there are other factors which have not been taken into account, of which moisture and unequal development of the larvæ when the cocoon is spun are probably the most important.

EFFECT OF THE INSECT UPON THE FRUIT.

The effect of the injury by the codling moth upon the fruit varies with the variety of the fruit and the season of the year in which the injury is done. The attack of the larvæ of the first generation usually causes the fruit to fall. A few of the fruits of fall and winter varieties, after having been injured, stay on the trees for the remainder of the season, but the early varieties fall quite rapidly and readily. In all cases the effect of the injury is to cause the fruit to ripen prematurely. The amount of the windfall of the late varieties depends in great measure upon the amount and violence of the wind.

The effect of the injury upon the value of the fruit is variable. If the inside of the fruit is eaten out, it is valueless except for use as cider apples. When the injury consists of only a small defect on the exterior of the fruit, it may be graded as second, and is of considerable value. Fruits often bear very small spots where the larvæ have pierced the skin but have failed to bore into the flesh of the apple. These spots do not materially injure the apple, and many of them are packed as first-class fruit. In cold storage apples which have been injured by the codling moth are the very first to begin to rot, and are consequently sources of contamination to the surrounding fruit.

THE PUPA.

The pupal stage of the codling moth is that stage in which the organs that are peculiar characteristics of the larva are broken down and worked over into the tissue of the adult. The pupa is about half an inch in length, and varies in color from yellow to brown, depending upon age, and when the moth is about to emerge it has a distinct bronze color. The head, eyes, mouth parts, antennæ, legs, and wings of the moth are apparent in sheaths which are immovably attached to the body. The abdominal segments, which are movable, are each armed with two rows of spines, except the terminal segments, which bear only one each. These spines point backward, and play an important part in the economy of the insect. The last abdominal segment has a number of long spines with hooks at the end. These hooks are fastened in the silk and aid the pupa in holding its place in the cocoon.

EMERGENCE OF THE MOTH.

After the pupa has thrust itself out of the cocoon, the pupal skin splits down the back, and the moth forces its way out by splitting away the head end of the pupal skin. The legs, antennæ, and wings are drawn out of their sheaths. The insect is wet, and the body wall is soft. The wings increase several times in size, and as the body dries it grows more rigid. A few moths were observed to have emerged in the field. During the process of expanding and growing they clung to the bark of the trees with their heads up (Pl. VI, fig. 1), avoiding the sunlight. When the wings were fully expanded the moths would often hold them over their backs for a few minutes, in a manner similar to the way a butterfly holds its wings. After running about over the tree for a short time the moths fly into the lower branches of the trees, and are lost to observation. Their quick and erratic flight is similar to that of other moths of this family. The whole process of emergence takes from fifteen to thirty minutes.

THE ADULT INSECT.

The adult insect or moth is quite variable in size. The wings expand from 14 to 19 mm. Commonly speaking, they never expand over three-fourths of an inch. The whole insect is covered with scales in varying colors. The tip of the front wings bears a large dark-brown spot or ocellus on which there are two irregular broken rows of scales, which have a coppery metallic color, and with some reflections of light they appear golden. Near the ocellus there is a very dark-brown band across the wing, which is more or less triangular in outline. The remainder of the wing is crossed by irregular dark and white bands, an appearance caused by the white tips on the dark scales. In many specimens there is a distinct darker band across the wing, while in others this band is not apparent. The hind wings are a grayish-brown color, darker toward the margin, with a long black line at the base of the fringe. The underside of the hind wings has dark, irregular, transverse markings. The underside of the front wings is of a light-brown color, with opalescent reflection and with a few markings except on the costa. The legs and head and patagia are covered with long, narrow, white-tipped scales, while the body is covered with white-colored scales with opalescent reflections. The large white scales on the caudal margin of the abdominal segments are especially conspicuous. (Pl. VII.)

HOW TO DISTINGUISH THE SEXES.

There are many characteristics by which the males and females may be easily distinguished. As stated by Zeller, the males have penciled, long, black hairs on the upper side of the hind wings. These hairs are sometimes of a light color, which renders them difficult to distinguish. Slingerland discovered that the males could also be distinguished by the presence of a distinct elongate, blackish spot on the underside of the fore wings, which spot consists of a number of black scales. These scales are sometimes of a slate color, which under certain lights renders the spot inconspicuous. There is a great difference between the genital organs of the two sexes, as the ovipositor of the female can be said to be hoof-shaped, and ends, roughly speaking, in a point; while the presence of the claspers on the male can be said to cause the abdomen to end in a line.

HABITS OF THE MOTH.

It is generally stated by writers that the adults of the codling moth are but rarely seen in orchards. In cases where the infestation is not very bad this is usually the case; but where the infestation is bad it is a very common thing to see the moths in the orchard, but never in any large numbers. They spend most of their time resting on the upper surface of the leaves or on the trunks of the trees, where they are hidden by their resemblance to the grayish bark. When disturbed, they fly away so quickly that the eye is unable to follow them in their erratic flight. According to many observers the codling moth feeds on the juice of ripe apples. The writer has often observed them drinking water in cages.

As the conclusion of many investigations by many persons and under various conditions, it has been definitely determined that the insect is not attracted to lights. A very few records of captures of codling moths at lights, usually of the accidental catching of one or two specimens, have been published.

DURATION OF THE LIFE OF THE MOTH.

LeBaron gives 1 week as the average length of the life of the adult codling moth, Washburn gives from 10 to 15 days, and Slingerland says that one moth lived in his cages for 17 days. Records of the writer in August, 1902, of forty-seven moths, show that two moths lived 1 day; ten, 2 days; eleven, 3 days; ten, 4 days; two, 5 days; seven, 6 days; one, 7 days; two, 8 days, and two, 9 days; giving a weighted average of 4 days.

The length of the adult stage depends upon the conditions under which the moths are kept, as they will live longer if there is water which they can drink. The average of 4 days was obtained when there was no water accessible to the moths; but had there been water or ripe fruit, the average would probably have been longer.

GENERATIONS OF THE INSECT.

The question of the number of generations of the codling moth in one season has for many years been in doubt. In recent years entomologists have been stimulated to greater efforts and have in a measure solved the problem. The economic importance of this question is very apparent, as the second generation of the insect inflicts about ten times as much damage as the first generation, and it is necessary to know whether a second generation is present in order that the proper measures of control may be employed. Great biological interest also attaches to this problem, as it affords an excellent opportunity for the study of the effects of different climates on one insect.

The term "generation" is used instead of "brood" because it describes more definitely the idea intended. A generation in this connection means a number of individuals which pass through certain stages at about the same time, having begun in the same stage at the beginning of any given season. A succeeding generation is the aggregate of all the different broods of the individuals of the generation immediately preceding. A new generation is considered to begin with the egg stage, and continues through all the transformations of the insect until the moth dies. Many authors object to the term "partial generation," but as there is a condition in which this term can be used with a definite meaning, it may be well to use it. For instance, in some sections of the country all the insects pass through one generation; a few, becoming more advanced than others, may succeed in passing through the pupal and moth stages and lay eggs, from which larvæ hatch and enter the fruit, whereas the majority of the insects hibernate as larvæ and do not transform until the following spring. As those insects which enter the fruit in the fall do not for the most part complete their development, at least in the field, they are termed a partial generation.

In tabulating the results of observations in regard to the time of the various stages we find that at certain periods more individuals of a generation are in certain stages than at other times; and likewise we find periods when there are fewer insects of a certain stage than at other times. These periods are designated respectively the maxima and minima of the different generations. It is always considered that the larvæ, pupæ, and moths found in the early spring belong to the last generation of the preceding season and may be termed the hibernating generation.

From the writings of European authors we find that there is but one generation of the codling moth in northern Europe, including England (Westwood) and northern and central Germany, while the evidence of Reaumur and Schmitberger shows that at Vienna and in France there are two generations. American writers have at various times recorded many observations of variations in the number of generations in the United States. Fitch seems to indicate the presence of but one generation, while Harris says a few may transform and enter the fruit in the fall, though the majority of the first generation hibernate. Fletcher reports that careful observations extending over ten years convince him that near Ottawa, Canada, there is but one regular generation of the insect, while in the fruit-growing districts of western Ontario there are two generations, the second being invariably the more destructive. The observations of Atkins, Harvey, and Munson agree with those of Harris. Slingerland says in 1898 that his observations indicate that in New York a large number of the larvæ of the first generation develop into moths, the percentage transforming depending upon the weather conditions of the season. In 1894 Smith found by a series of observations that the larvæ collected in midsummer did not transform further that year, but hibernated. Later, in 1897, he states that near New Brunswick, N. J., there is positively only a single annual generation, and, further, that south of Burlington County there is at least a partial second generation. In addition to the observations already given of conditions quite similar to these in New Jersey, we find that Trimble in 1865 carried out a very careful and accurate series of experiments upon the life history of the codling moth at Newark. He found that on August 10 there were three pupæ among the insects under observation, and that on August 20 many moths had emerged; on August 23 he found that one in five of the larvæ had transformed. Sanderson finds that there is one generation and a partial second generation in Delaware. He states that of the larvæ found July 31 about 29 transformed and 5 remained as larvæ. Taking these numerous observations and the data given in regard to them into consideration, we must conclude that Doctor Smith's observations are too few in number and do not justify the assertion that there is but one generation of the codling moth at New Brunswick. Many observers in widely different sections of the United States have found two generations clearly defined. Le Baron states that "in the latitude of Chicago a great majority of the moths of this brood (first) emerge the last two weeks in July." Riley, after many years of close observation, states that the insect is "invariably two brooded in Missouri." Popenoe and Marlatt found two generations in Kansas. Gillette indicates two generations in Iowa. Walton by breeding experiments discovered two generations in the same State. From a series of observations extending over several years, checked by breeding experiments, Cordley concludes that there are two generations at Corvallis, Oreg. Koebele says there are two generations in the Santa Cruz Mountains of California, and the insect probably does not differ in its habits throughout the State. Based upon one of the most extensive studies of this question that has ever been made, Gillette arrived at the conclusion that there are two generations in Colorado. Cooley says that in 1902 there were two generations at Missoula, Mont. Forbes indicates a third generation in Illinois, based upon the fact that very young larvæ were found on October 4. Coquillett states that his notes indicate that the insect has three generations in California. Washburn says there are three to four generations at Corvallis, Oreg. Card gives two to four in

Nebraska. Cockerell concludes there are three full generations near Mesilla Park, N. Mex. Aldrich in 1900 stated that there were three generations in Idaho, and in 1903 concluded after a series of breeding experiments that there was a partial third generation at Lewiston. At various times writers have made assertions that in the warmer sections of the United States a partial fourth brood was produced.

In carefully sifting all these statements the writer finds many points which throw doubt upon and render them of but little value, principally because definite dates and localities are not given. The date and exact localities are often of as much importance to future workers, and perhaps of more importance, than the observation itself.

METHODS BY WHICH THE NUMBER OF GENERATIONS MAY BE DETERMINED.

From the nature of the case the determination of the number of generations of the codling moth is a most difficult problem to solve accurately. The methods used must be scrutinized carefully, and all possible sources of error must be taken into consideration or eliminated. The correctness of a conclusion can be assured only by exactness in methods and by corroborative evidence secured by different methods. Observations made in orchard examinations have constituted one of the methods largely followed. Although observations are of great value when used in connection with other methods, they often lead to erroneous conclusions when used alone, as it is possible to obtain evidence of the condition of an orchard only from the study of a very small portion of it during a very short period. Past conditions are often unknown, and conclusions obtained are largely based upon preconceived ideas. If a large number of insects can be bred throughout the season, much valuable data can be secured and the problem solved beyond any doubt. As yet we have no records of breeding experiments carried on throughout the season with the necessary accurate data. The writer has attempted many times to breed the insects throughout the season, but has always failed, usually on account of some unforeseen difficulty which caused the experiment to end. However, it is believed that with proper care and experience this breeding can be successfully done. Breeding the insect and harmonizing the results of the breeding by observations in the orchards has been the method most used in working upon this question. By breeding the insect through parts of its generations valuable data have been secured, which, if pieced together and corroborated by other methods, are almost as valuable as if the insect had been bred throughout the season. Many entomologists have neglected to increase the value of their breeding experiments by keeping the insects under conditions of temperature and moisture different from those prevailing in the orchard and keeping no record or a very fragmentary record of the temperatures to which the insects were subjected. Many other records are questionable by reason of the fact that the generation, or the nearness to the maximum of the generation, of the insects placed in the cage was uncertain or unknown.

Early in his studies of the life history of this insect the writer saw the necessity of finding some method by which the numbers of individuals of a generation could be approximated at certain times. By an incidental study of the records of larvæ captured under bands, published by Professor Aldrich in 1900, it was noted that at a certain time in the season there were fewer larvæ so caught than at periods of time immediately following and preceding. By collecting as many records as were obtainable at that time, it was observed that these conditions were quite constant. The periods of the larger and smaller number were termed, respectively, the maximum and minimum of larvæ entering bands.

In 1901 many fruit growers in Idaho, at the request of the writer, kept and submitted records of the larvæ killed under bands. Other records, many of which had been made without any idea of the future use to which they might be put, were collected from many sources. These records were tabulated and curves were drawn upon cross-section paper, using the time as one factor and the number of larvæ as the other. These curves give quite an accurate picture of the course of the insect in the orchards throughout the season. Not all of the records, however, were satisfactory, as a few of them from various causes gave data which were of no value. The curve showing the effective temperature at the dates at which the larvæ were killed under the bands was drawn upon the same charts and gives quite accurately the effect of the temperature upon this habit of the insect. A number of these records are reproduced (figs. 5 to 16).

INACCURACIES OF THE RECORDS.

There are many sources of possible inaccuracy in these records. The greatest inaccuracy is probably found in the weekly or biweekly band records, because these are composite records of many individual trees and show only approximately the dates of the maxima and minima. Many of the records were commenced too late in the season to be of any real value; and when they were started even a little late the curve ascends with rapidity, which would not have happened had the record been started earlier. In consequence of a series of warm days, the maximum number of larvæ may enter the bands sooner than they would if the temperature had remained normal; and if the temperature be low for many days, the maximum might be later than it would be normally. Spraying might seriously interfere with the accuracy of the record, as at certain periods all of the larvæ entering the fruits might be killed and thus cause a fall in the curve of larvæ entering

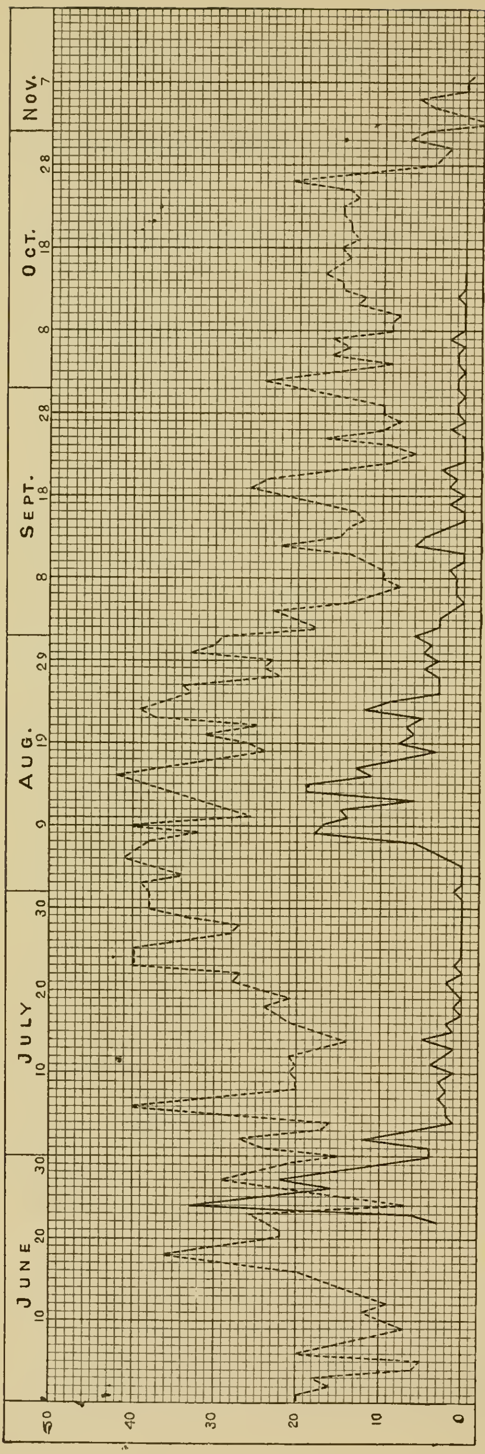


Fig. 5.—Daily band record made by H. G. Gibson, Nampa, Idaho, in 1901, upon 4 trees. (Note the relation of curve to dotted line, which indicates effective temperature.)

bands. When counted the larvæ were killed, which reduced the number of larvæ of the succeeding generation. If the tree from which the record is taken should be covered with rough bark or have a large number of holes and cracks in it, the number of larvæ entering the bands will not be so great as if the band were the only place in which they could hide to spin their cocoons; therefore, filling the holes and scraping away the rough bark would cause a rise in the curve.

In most cases the conditions which would render the records inaccurate were eliminated when it was possible to do so. In order to show the relations between the daily and the weekly band records, a weekly summary (fig. 6) was made of Gibson's daily band record. By this means it was shown that the weekly records are only approximate, and show the general trend of the insect in the orchard rather than any details. One writer has suggested that the rise and fall of the temperature would cause a corresponding rise and fall in the number of larvæ, so as to obscure the true position of the maximum. By a study of the record made by Mr. Gibson (fig. 5), in which the effective temperature is shown by a dotted line, many interesting facts in regard to the temperature can be observed. It must be noted, however, that the number of larvæ caught on any given day is influenced by the temperature of the preceding day, as most of the larvæ enter the bands at night, some time before midnight, and that they are usually killed and counted some time the following morning, while the observations upon the temperature were taken at 6 a. m.

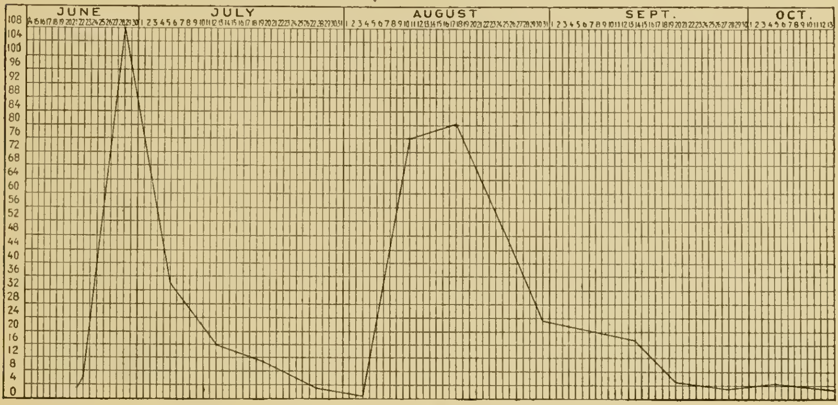


FIG. 6.—Weekly summary of Mr. Gibson's band record.

and 6 p. m. The great rise which occurred on June 24 was probably due in a great measure to the fact that the bands were placed upon the trees on the 21st. The fall in the number of larvæ on June 24, the rise on June 27, the fall on June 30, the rise on July 1 and 2, and the fall on July 4 can be partially accounted for by the corresponding rise and fall of the temperature. From about July 5 to August 4 the

FIG. 7.—Band record made by William A. George, Caldwell, Idaho, in 1901.

temperature was high, but there was no corresponding rise in the number of larvæ, as there were no larvæ ready to enter the bands, the majority of the insects being in the moth, egg, and younger larval stages. This interval of few larvæ marks the time between the maxima of the generations entering the bands. In the second maximum it can be noted that the rise and fall of the number of larvæ is usually parallel with that of the temperature, but toward the end of the record the temperature has but little influence. The record made by Mr. George (fig. 7) and Mr. Ayers (figs. 8 and 9) show practically

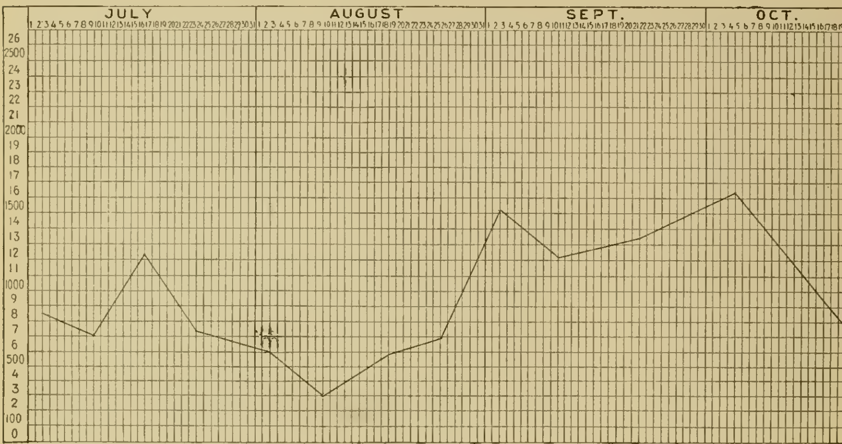


Fig. 8.—Weekly band record made by Mr. Ayers at Boise, Idaho, in 1897, on 140 trees.

the same conditions, but not so clearly, on account of the length of time between the observations.

LENGTH OF THE LIFE CYCLE.

In order to establish a correct basis for the determination of the number of generations, it is essential that we determine as closely as

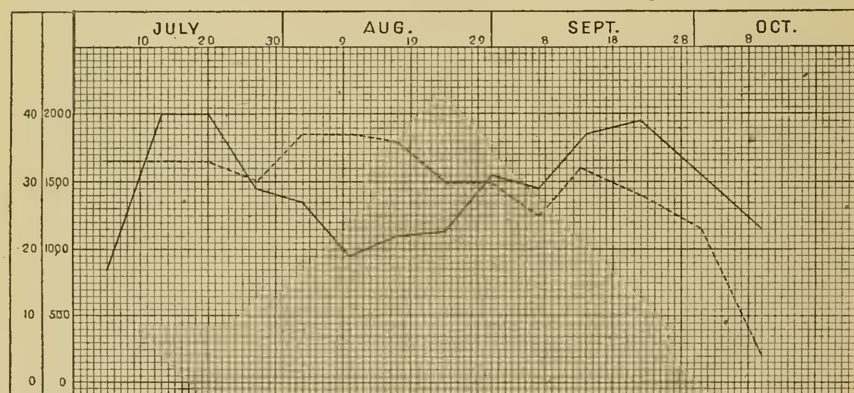


Fig. 9.—Band record made by Mr. Ayers in 1898.

possible the average number of days in which the insect can pass through one generation. Assuming a certain date, with as much accuracy as possible, when the maxima occur in a band record, and taking into consideration all the imperfections of the records, we should have approximately in the number of days between these max-

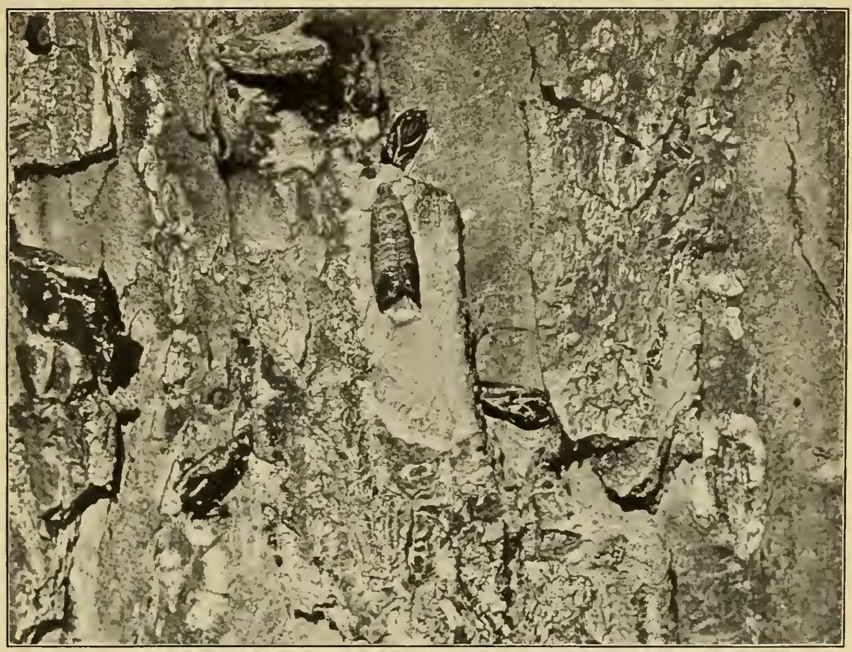


FIG. 1.—LARVÆ, PUPÆ, AND MOTHS ON ROUGH BARK.

FIG. 2.—INFESTED APPLES BEING BURIED.

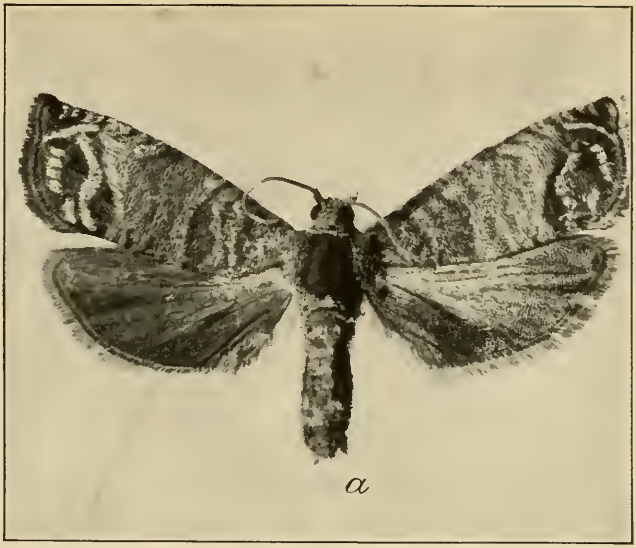


FIG. 1.—CODLING MOTH (ENLARGED 4 TIMES).

Wing on the right shows the reflections from the gold-colored scales in the ocellus.

FIG. 2.—CODLING MOTHS (ENLARGED TWICE).

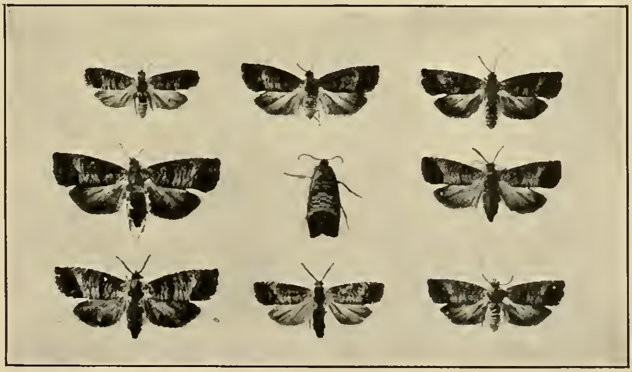


FIG. 3.—CODLING MOTHS (NATURAL SIZE, FROM SLINGERLAND).

ima the length of the life cycle of the insect. In the records given we find that the periods vary from 40 to about 66 days, with an average of 55 days, or about 8 weeks. Professor Gillette finds that according to his life history studies upon the summer brood the

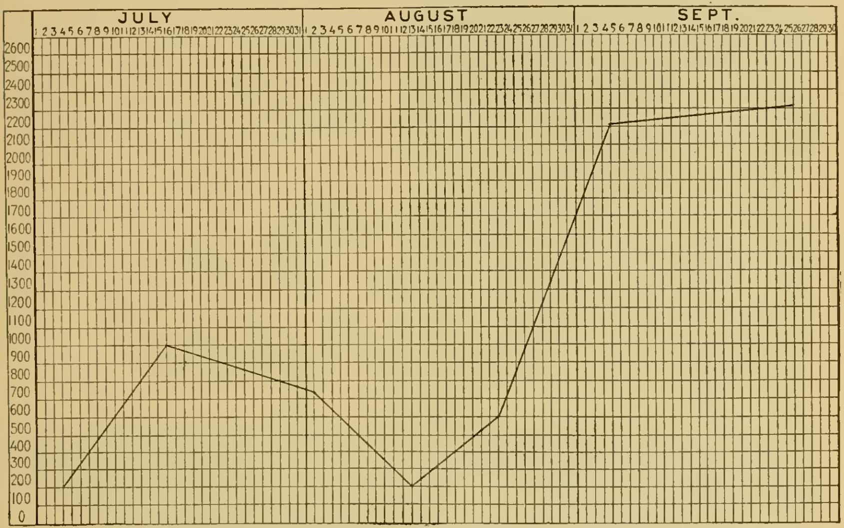


FIG. 10.—Band record made by David Brothers in Colorado in 1899.

period of the different stages is as follows: From egg to larva, 7 days; from larva to cocoon stage, 19 days; from cocoon stage to emergence of moth, 18 days; from emergence of moth to middle of egg-

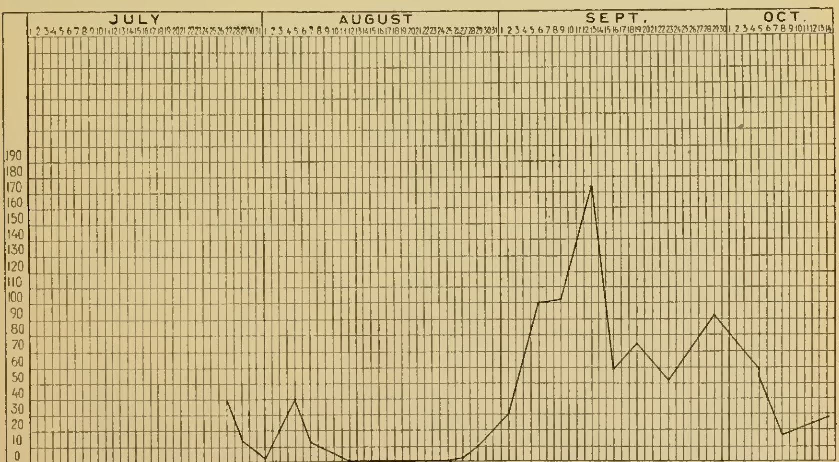


FIG. 11.—Band record published by Prof. C. P. Gillette, taken on 14 trees, at Fort Collins, Colo., in 1900.

laying stage, 5 days (estimated); total, 49 days, or 7 weeks. From the writer's numerous records of the lengths of the different stages, however, it is found that most are somewhat longer than those given by Professor Gillette and that the egg stage averages about 11 days; from the hatching of larvæ to leaving the fruit, 20 days; from entering the bands to emergence of moth, 22 days; from emergence of moth to middle of egg laying (estimated), 5 days; making a total of 58 days, or about 8 weeks. By adding together the shortest times and the longest times, respectively, we find the minimum length of the life cycle to be 36 days and the maximum 100 days. This period of 55 to 58 days having been obtained by these two widely different methods, they are probably not far from the correct average length of the life cycle of the codling moth.

SEASONAL HISTORY.

By following the development of the codling moth through the season as carefully as possible, we are enabled to throw more light upon the question of the number of generations. Those larvæ which have escaped their enemies during the winter, if left in the field, change to

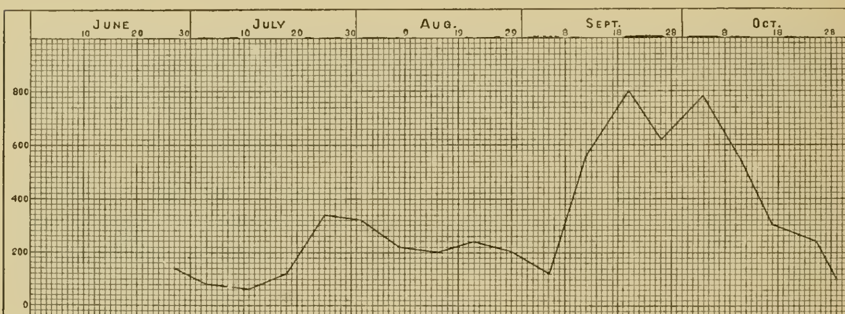


FIG. 12.—Band record made by Prof. E. A. Popenoe, Manhattan, Kans., in 1890.

pupæ, according to Slingerland, just prior to the time when the apple trees are in bloom. He found the first pupæ April 27, and by the 7th of May about one-fourth had pupated. In 1902 the writer found the largest number of pupæ about the time the apples were in bloom. Some were found in rotten wood as late as June 10. The location of the larva has the greatest influence upon the period of pupation, those in warmer places pupating more quickly than those in colder situations.

EMERGENCE OF THE MOTH.

From the records of various writers, as compiled by Gillette, we find that the first moths appeared from April 24 in New Mexico to about May 16 at Corvallis, Oreg. Mr. McPherson records that in 1901 he found a moth in the field in Idaho as early as April 23, and that the moths were most numerous about May 1. Mr. Hitt in breeding 50 moths found that the first emerged May 5 and the last May 28. In 1902 the writer found that the majority of the moths emerged between

May 15 and 20. Cordley states that in Oregon in 1899 moths emerged in some cases April 10, and continued to do so until July 1. At Ithaca, N. Y., Slingerland found in 1896 that moths emerged from May 3 to June 22, and in 1897 from May 24 to June 7. Gillette records that he found moths out of doors at Fort Collins as early as April 26. The extreme range in time of appearance of these moths was 69 days in their cages. At Fort Collins, according to Mr. Hitt's records, this period extends over about 23 days. Professor Slingerland found that this range was 49 days in 1896.

RELATION BETWEEN EMERGENCE OF THE MOTH AND THE BLOOMING PERIOD.

Slingerland states that the moths begin to emerge in New York about the time the apples are in bloom, but the majority do not emerge until after the blossoms fall, and but few larvæ are found to enter the fruit until about two weeks thereafter. Gillette found the first moth emerging about 10 days before the trees were in bloom. He states that the majority of them emerged about the time of bloom, but eggs were found July 9, 1900, and June 19, 1901, and were all hatched by July 21, the trees having been in blossom about May 5 to 15. This would make about a month between the blooming period and the time when the

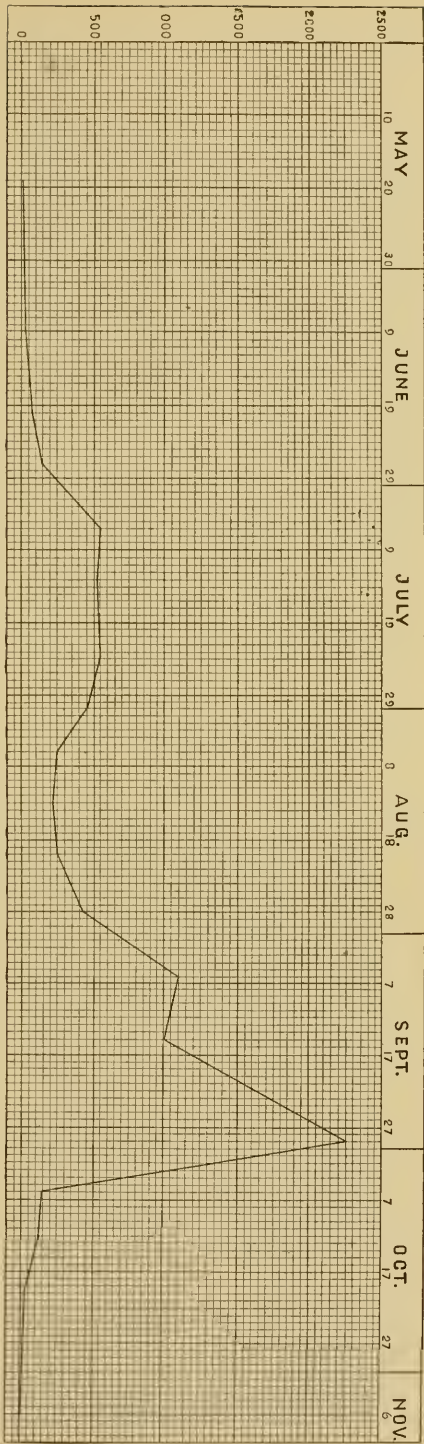


Fig. 13.—Band record made by Chapin on 850 trees in San Jose, Cal., in 1883.

first larvæ hatch and enter the fruit. Card found the eggs about three weeks after the blossoms had fallen. Cordley found that in 1898 the first larva entered the fruit about July 1, the egg from which

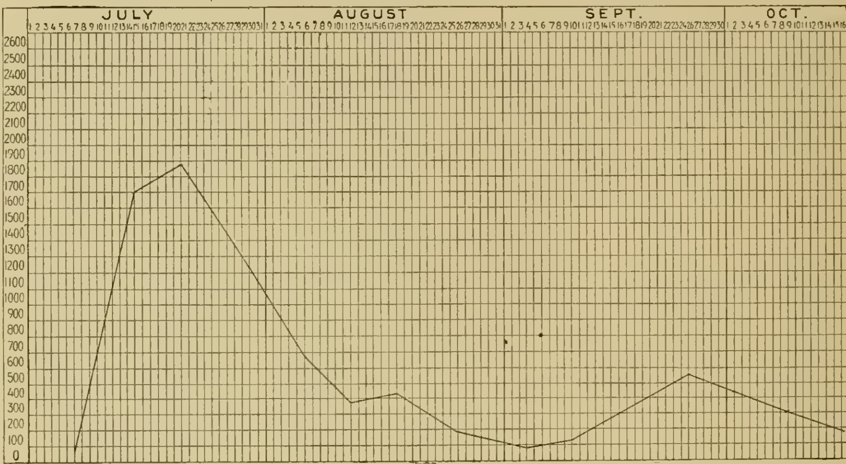


FIG. 14.—Band record made by Prof. J. M. Aldrich, Juliaetta, Idaho, on 40 trees, in 1899.

it hatched having probably been deposited about June 21. This entering of the fruit took place about two months after the petals had fallen. The writer found that in southern Idaho in 1902 the apples were in full bloom about May 13, and the first larvæ were noted to

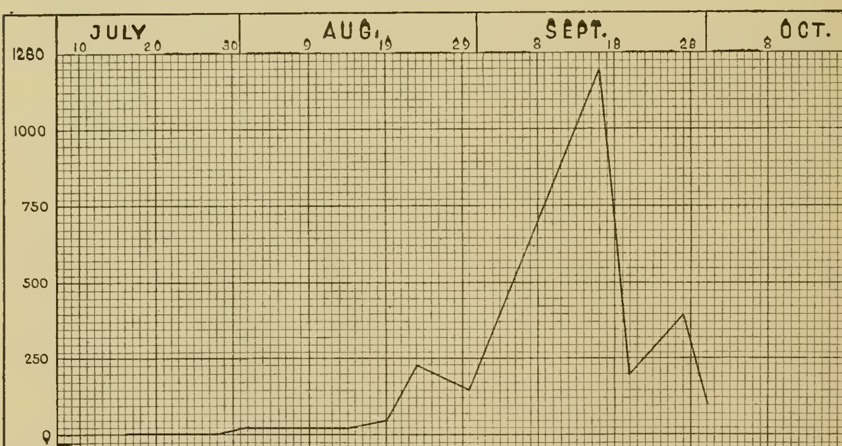


FIG. 15.—One of the records made by H. E. Burke at Boise, Idaho, in 1902, to determine the maximum of the second generation.

have entered the fruit June 11, or about 25 days after the blossoms had fallen.

From these few observations we find that the moths may emerge some time before the apples are in bloom, and, depending largely upon locality, the larvæ begin to enter the fruit from a week to two months after the blossoms have fallen. From the standpoint of the orchardist this is a most important question in considering the effect of the first spraying upon the insect.

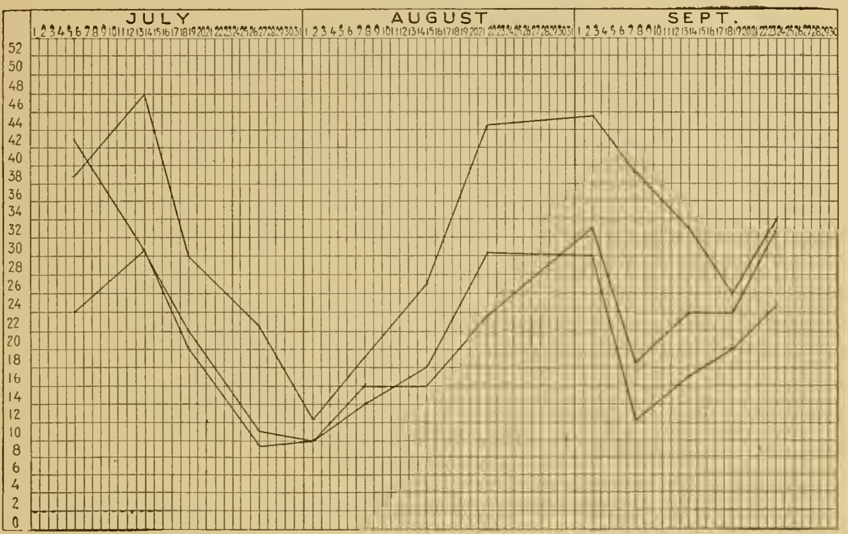


FIG. 16.—Record by H. C. Close, Utah Agricultural College.

The next point at which we can make any definite observations upon the codling moth is when the larvæ are leaving the fruit and entering the bands for the purpose of spinning their cocoons. The band records give this most valuable data in a very accurate manner. The following table shows the maximum of the different generations entering the bands, according to these records:

TABLE VI.—*Maximum of larvæ killed under bands.*

Year.	Locality.	Observer or source of record.	Number of trees.	First maximum.	Second maximum.	Days between maxima.	Total number of worms.	Time of removal of bands.	Average number of worms per tree.
1897	Boise, Idaho......	Mr. Ayers	140	July 17	Sept. 15	61	12,247	Weekly....	87.48
1898	.....do	.....do	140	July 10	Sept. 10	62	20,909	.....do	149.35
1899	Juliaetta, Idaho..	Prof. J. M. Aldrich	40	July 20	Sept. 24	66	8,620	.....do	215.50
1901	Nampa, Idaho....	H. G. Gibson	4	June 26	Aug. 16	51	467	Daily	116.75
1901	Payette, Idaho ...	J. Shearer	3	July 18	Aug. 17	60	215	Weekly....	71.66
1901	.....do	.....do	80	July 1	Aug. 30	61	3,554	.....do	41.42
1901	.....do	.....do	128	July 5	....do ...	56	1,690	.....do	13.2
1901	Provo, Utah	Utah Agricultural College.	23	....do ...	Sept. 2	59	4,141	.....do	180
1901	.....do	.....do	26	July 13	Aug. 27	45	2,829	.....do	108.2
1901	.....do	.....do	31	July 5	Sept. 2	50	2,880	.....do	84.7
1901	Hagerman, Idaho	R. E. Connor	27	July 12	Sept. 4	54	194	.....do	8.2
1901	Lewiston, Idaho..	S. G. Iasman	4	....do ...	Sept. 10	60	666	6 per month	166.6
1901	Caldwell, Idaho..	Wm. C. George ...	10	June 25	Aug. 13	49	640	2 to 5 days.	64
1899	Colorado	David Brothers...	....	July 16	Sept. 15	61	......	Weekly....	......
1890	Kansas	E. A. Poponoe....	....	July 25	Sept. 28	65	......	.....do	......
1883	San Jose, Cal	Chapin	850	July 19	Sept. 23	66	......	.....do	......

Riley states that the larvæ of the first generation are most abundant about July 8; Gillette, that this occurs in Grand Junction about July 15, at Denver July 21, and at Fort Collins July 25.

MOTHS OF THE FIRST GENERATION.

Card found the first moths of this generation about July 2. Cordley gives August 1 as the date for the first and September 15 for the last. Gillette gives the following data: Grand Junction, Colo., first July 28, last September 12; Canyon City, first July 15, last September 10; Fort Collins, first July 13, last September 12. According to Gillette, the eggs of the first generation were most abundant August 12. In 1901 the writer found eggs most abundant between July 15 and August 4. In 1902 they were most abundant about the same time, but were obtained in cages as late as August 29. The dates of the maxima of this generation of the larvæ going under bands is well shown in Table VI for the second generation. An examination of these band records as published shows that the period of the larvæ leaving the fruit and entering the bands extends over two months.

HIBERNATION.

The following table by Gillette shows the time at which pupation ceased and the larvæ began to hibernate at various places in Colorado. It was found, as shown by the table, that pupation ceased between August 10 and August 30, varying with the locality in which the experiments were made.

TABLE VII.—*Proportion of hibernating larvæ taken at different dates.*

Locality.	Dates larvæ were taken.	Number taken.	Number hibernating.	Record by—
Grand Junction, Colo	July 16–23, 1900	33	1	Silmon Smith.
Do	July 24–30, 1900	53	3	Do.
Do	July 31–Aug. 6, 1900	60	8	Do.
Do	Aug. 6–13, 1900	....	....	Do.
Do	Aug. 13–20, 1900	79	78	Do.
Do	Aug. 21–29, 1900	130	130	Do.
Do	Aug. 30–Sept. 4, 1900	192	192	Do.
Rockyford, Colo	Aug. 1–6, 1900	22	5	H. H. Griffin.
Do	Aug. 7–11, 1900	14	4	Do.
Do	Aug. 12–14, 1900	51	14	Do.
Do	Aug. 15–21, 1900	66	56	Do.
Do	Aug. 22–28, 1900	115	115	Do.
Do	Aug. 29–Sept. 6, 1900	80	80	Do.
Canyon City, Colo	July 30, 1899	25	0	Dr. R. J. Peare.
Do	Aug. 1–13, 1899	70	30	Do.
Do	Aug. 14–20, 1899	50	44	Do.
Do	Aug. 21–28, 1899	100	99	Do.

Cordley has for several years been unable to breed any moths after September 15. In 1900 the writer found that pupation had ceased September 1, and in 1901 September 7. In 1902 more extensive breeding experiments were carried out, from which it was found that pupation began to grow less about August 1 and entirely ceased August 22, and that no moths emerged after September 17.

At various times records have been made of finding single moths late in the season, in October. The presence of these moths can be easily accounted for by the fact that the larvæ probably got into some place where the general outside temperature had no effect on them, and increased temperature caused transformation.

EVIDENCES OF A THIRD GENERATION.

It is often found that in September a large number of the fruits have been entered by very young insects, and it is also found that in some localities these injuries extend into October. This has given rise to the belief that there is a third generation present; and not having definite records in regard to the life history of the codling moth, many fruit growers have come to the conclusion that there are three generations, and some have even gone so far as to say that there is a partial fourth generation. Many entomologists have taken these statements from the fruit growers, and not having given as complete study to the subject as was possible, have published the conclusion that three generations were present. The writer has collected all of the publications in which three generations were either indicated or given as occurring, and has, with the greatest of care, studied the observations upon which the conclusions were based. Many entomologists have submitted original notes or copies of the notes from which their conclusions were drawn. After carefully studying all these records and published accounts the conclusion was reached that there were only two publications in which any substantial evidence is given as to the existence of a third generation of the codling moth. Professor Cockerell, in a bulletin of the New Mexico Experiment Station, concludes that there are three generations and a partial fourth. Professor Cockerell relied mainly upon observations, and checked these observations by breeding experiments in only a few instances. The observations, while of value, give the conditions in the orchard at irregular intervals, and then only for a very short period of time. Many erroneous conclusions were drawn from these observations. For instance, the finding of an empty pupa case on June 26 was considered an evidence that the moths of the first generation had emerged. In view of the fact that Professor Gillette finds that the extreme period of emergence of the moths in the spring is 69 days at Fort Collins, and that Professor Slingerland found moth in New York as late as June 22, we see that there is the greatest probability that these moths were the latter part of the hibernating generation, instead of the first part of the first generation. The finding of wormy apples on July 3 was considered as the beginning of the second generation entering the fruit. On August 12 small larvæ in fruit were considered to be the beginning of the third generation. Anyone familiar with the conditions of Western orchards knows that small larvæ entering the fruit can be found almost any time in the summer. From the evidence given by Professor Cockerell the writer is of the opinion that there are only two generations of the insect present in Mesilla Park, and that there is no sufficient evidence of a third.

Professor Aldrich in a recent bulletin states that, in his opinion, there is at least a partial third brood at Lewiston, Idaho. This conclusion is arrived at as a result of some very carefully conducted experiments which give evidence, by breeding records, which up to a certain point is indisputable. By caging the insects at proper intervals Professor Aldrich obtained moths of the second generation on September 3 and 4. There is no doubt in the mind of the writer that these were moths of the second generation. But Professor Aldrich failed to state whether or not he obtained eggs from these moths, and instead of doing so took unknown field conditions to carry out the remainder of his experiments, taking it for granted that the larvæ entering after September 6 hatched from eggs which had been laid by moths of a similar age to those emerging September 3 and 4. As the latter were of the very earliest of the second generation, there is no reason for assuming that the larvæ which entered after this time were not larvæ of the retarded portion of the second generation. By using the length of the life cycle with the data given it is obvious that these larvæ belong to the second generation instead of a third.

CONCLUSION.

By taking into consideration the evidence which has been derived from the band records, from breeding experiments, and observation, the writer has no hesitancy in concluding that there are but two generations of the codling moth in the arid sections of the West, and that it remains to be proven that even a partial third generation of the insect is present in any part of the United States. The writer admits, however, the possibility of a partial third generation in the West and South, and that careful, accurate work in the future will give us better evidence upon this point and settle the question beyond a doubt. By a careful study of the temperatures for several years in the localities where observations have been made upon the number of generations of the insect, the writer hoped to be able to give the total temperature at which the different conditions in regard to the generations might occur; but after a great amount of labor this was found to be impracticable, principally on account of insufficient accurate observations upon the insect, and it was decided to make use of the more general life zones in determining the distribution of generations. It may be stated that the boundaries between these life zones are only approximate; that there are different gradations between them, and that as yet there are many inaccuracies in the map. Mr. Marlatt, from personal experience and the observations of other entomologists, arrived at the conclusion that there was one generation of the insect in the transition zone, two in the upper austral, and three in the lower austral. By using the conclusions of recent years the writer finds that there is one generation in the transition zone, with often a partial second, two generations in the upper austral, and two in the lower austral, with a possibility of a partial third.

NATURAL CONDITIONS WHICH TEND TO DECREASE NUMBERS.

It has often been noted that a sudden fall of temperature is fatal to a large number of the smaller larvæ of the codling moth. It has been already noted that Professor Aldrich has recorded such an observation. Hot sunshine and extreme dryness cause many of the pupæ in the case to die. A moist climate aids fungi and bacteria to such an extent that sometimes most of the larvæ are killed by them. Larvæ that are killed by fungous diseases are hard and mummified, and have a whitish appearance. Bacteria cause the internal organs to disintegrate and the larva to become limp and full of juices of a brown color.

NATURAL ENEMIES.

Although the codling moth has many natural enemies, the number as compared with those of other Lepidopterous larvæ is comparatively small. This may be accounted for by the fact that the insect throughout the greater part of its life is more or less protected, but when the larvæ have left the fruits and are seeking places in which to spin their cocoons and when in the winged stage they are attacked by numerous enemies. Birds are by far the most efficient natural enemies of this insect. Anyone who tries to collect the larvæ from the trunks of trees in spring will find very few specimens, but, on the other hand, will find many empty cocoons. The writer has many times in the spring searched persistently for larvæ in the rough bark and the more exposed cracks, but found practically none, although many could be secured by cutting into the holes and cracks of the tree. Riley, Walsh, and Slingerland also note this effectiveness, and the amount of good the birds do can only be estimated. The cocoons are always found, and on a close inspection of the bark a telltale hole discloses the story of some woodpecker's work. It has often been noted also that the same birds have made holes or enlarged the cracks in the stubs of old branches for the purpose of digging out the larvæ. Plate VIII, figs. 1, 2, 3, shows stubs of branches from an old orchard near Elkton, Md., in which these birds have done efficient work in reducing the number of larvæ during the spring. Fig. 2 is especially interesting, as on close examination it shows the following points: Some time in 1900, in the course of pruning the orchard a branch was cut away, leaving the stub, which is 8 inches long. In the following winter and spring the stub began to crack and decay and the bark to loosen. Many codling-moth larvæ crawled under the bark in the fall of 1901. The woodpeckers found this stub in the following winter and spring, and not only probably secured all the larvæ which were under the bark, but enlarged one of the main cracks in order to get those which were hidden inside. In the fall of 1902 all the bark had fallen from this stub and many more larvæ took refuge in the cracks. Upon examination, in May, 1903, the writer found that the crack had been recently enlarged, as is well shown in the reproduction. This recent enlarging was probably done mostly by the pileated woodpecker (*Ceophlœus pileatus*), as the chips broken out were quite large, and probably required more strength than other smaller woodpeckers could muster. This stub was sawed from the tree and sent to the writer, and in the latter part of May the moths emerged, and 28 empty pupal skins were found on June 25. The writer estimates that fully 100 larvæ hibernated in this stub.

It is highly probable that all woodpeckers feed on the codling moth larvæ. Other birds, including the nuthatches, black-capped titmice, wrens, bluebirds, crows, blackbirds, kingbirds, swallows, sparrows, chickadees, and jays, may also feed upon the codling moth, especially those birds which winter in the locality where the larvæ are present. Without doubt the bobwhite quail, which has been introduced into many sections of the West, also feeds upon this insect. At best our knowledge of the food habits of many of these birds in regard to the codling moth is based upon but little direct evidence; but reasoning from what we do know positively, there is little doubt that codling moths form a part of the diet of at least some of these birds. Not many years ago a movement was set on foot in the Pacific northwest to import the German kohlmeisen into this country, as it was said to feed largely upon the larvæ of the codling moth; but because the benefits derived from the bird in its native home were not clearly proven, and that it sometimes injured fruit, and also on account of many disastrous experiences in the importation of birds and mammals which have already been made, the majority of the authorities were convinced that it would be a dangerous experiment, and no further action was taken. The expenditure of time and money necessary to carry out such a project would probably be more beneficial if applied to the protection of our native birds.

Koebele writes that in California he knows of many small bats flying around the apple trees in the evening, taking moths on the wing, and even darting down to take moths which were upon the leaves. The writer has often noticed bats flying about the apple trees, but was unable to obtain any evidence that they were catching codling moths.

INVERTEBRATE ENEMIES.

The writer has often found moths in limb cages dead with spider's silk wound around them, but made no further observations. The insect enemies of the codling moth are either predaceous or parasitic, and are quite numerous as to species, but are usually few as to individuals. A large number of predaceous insects in the larval stage have been observed feeding upon the codling moth, the following list being compiled from publications of various authors:

Chauliognathus pennsylvanicus.	*Pterostichus californicus.*
Chauliognathus marginatus.	*Calathius rufipes.*
Telephorus bilineatus.	Dermestid.
Trogosita corticalis.	Clerid.
Trogosita laticollis.	Chrysopa.
Trogoderma tarsalis.	Raphidid.
Perimegatoma variegata.	

In regard to many of these predaceous insects it is doubtful whether they feed upon the living codling moth larva or upon dead specimens. At best, they do not reduce the number of the larvæ to any considerable extent. In Utah a species of Ammophila was found stocking its burrows with larvæ of the codling moth. It is also recorded in California that *Sphecius nevadensis* was found pulling the larvæ out of their burrows.

Many observers have found the eggs parasitized by a species of Trichogramma. Even in its protected life the larva is preyed upon by many parasitic insects, among which are the following:

Goniozus sp.	*Pimpla annulipes.*
Macrocentrus delicatus.	*Bethylus* sp.

The writer found traces of three species of parasitic Hymenoptera which were preying upon the codling moth in the Pacific northwest, but was unable to breed any of them. Among the Diptera only one parasite is mentioned, namely, *Hypostena variabilis.*

In general it may be said that these parasitic insects are found in such numbers to be of value only in neglected orchards, and in any orchard that is well taken care of, sprayed, banded, and otherwise treated in preventive and remedial ways, these predaceous and parasitic insects are found in very small numbers or are entirely absent.

Even with the host of enemies arrayed against it, the codling moth under normal conditions in the West will ruin practically all of the apple crop, and if success is to be obtained proper measures of control by human agencies must be instituted, and the parasitic and predaceous enemies left out of the question, except woodpeckers, which may be encouraged with profit.

HOW TO COMBAT THE INSECT.

The codling moth seems to have been present and injurious in orchards for centuries, but until about eighty years ago no one seems to have made any suggestions as to how its ravages might be checked. It would require volumes to contain all that has been written about the methods which have been used against this insect—most of them valueless. Before considering methods of combating the insect there are several points which must be discussed.

Many of the Western States have horticultural laws which aim at extermination, and many of the corps of inspectors are working with that end in view; others, however, from recent experience have been led to change their views upon the subject. When one discusses the extermination of an insect he ventures upon debatable ground. As yet no insect has been exterminated through the agency of man, and judging from past experiences the writer believes that it is impossible to exterminate the codling moth even in a single orchard. The control of it, by means by which the damage it inflicts is reduced to a minimum, is the very best that we can expect to accomplish. It is a prime necessity, in order to make recommendations of value, that the entomologist have an accurate knowledge of the life history of an insect. Not only is this necessary for the entomologist, but it is essential for the fruit grower also to understand it, in order that he may apply recommendations intelligently and vary them to suit conditions. The erroneous ideas some fruit growers have upon the life history of the codling moth are sometimes startling, following recommendations simply because they are given to them, and having no idea of the reason therefor. Often they obtain good results, but more often failures result; and as they do not understand the reasons for the recommendations, they are at a loss to know why they did not obtain good results. To combat the insect successfully the fruit grower must be familiar with all the stages of the insect, the sequence of the stages, where found, and habits and variations. He should also be informed how the preventive and remedial measures act in reducing the numbers of the insects. With this knowledge he will be able to vary the recommended preventive or remedial measures to exactly fit his local conditions, and if any failures occur he will in a measure be able to tell why they occur, and the following year the experience will aid him in changing his methods in order to obtain better results. He will also be protected against using methods which are of no value, and will thus avoid a large unnecessary expense.

PREVENTIVE MEASURES.

Preventive measures are those which not only aid in controlling the codling moth, but aid the fruit grower in training trees so as to bear more fruit, support it while growing, and produce fruit of a better quality, size, and color. Although many of these questions are not closely allied to the control of the codling moth, they are of importance, as anything which increases the margin of profit aids in securing better general results from an orchard.

There are many methods of prevention which may be applied to keeping the insect out of a section of the country in which it is not yet present. By study of the means of its spread it will be learned how it may have entered the country, and by closing all possible avenues of introduction immunity may be secured for many years; but if fruit is being continually shipped into a new country from an infested district, it is only a question of a few years when in spite of all that can be done the insect will gain a foothold. Whether it becomes injurious or the loss is nominal will depend upon many conditions.

Many orchardists who have planted young orchards in infested districts are quite desirous of keeping the codling moth out of their orchards as long as possible, but if there are infested orchards near by this is a practical impossibility. It may be said that money and labor spent in keeping the insect out of a section or an orchard will accomplish more good if directed toward the study of better orchard methods and adapting the measures of control to that section of the country.

To insure the best results in the planting of a young orchard in an infested locality the codling moth should be considered from the very first, and everything that is done should be done only after taking into account the actual or probable presence of the insect. If note is taken of these methods and they are faithfully carried out, a great amount of labor and loss will be saved when the orchard is in bearing. There are many questions which can be decided for each locality only after all the conditions over which the fruit grower has no control, such as transportation, exposure, temperature limits, and proximity to water, have been fully considered. Although the question of soils is very important, by appropriate methods the character of some soils can be materially changed, as by cultivation, cover crops, and other means. The first question which confronts a man wishing to plant an orchard is the question of varieties, which is one of the most difficult problems to be solved. The soil, the climate, the purpose for which apples are grown, and various other factors, must be considered, each one having its own bearing upon the problem. If a home orchard, the likes and dislikes of the grower are the first consideration, but if the aim is to plant and maintain a commercial orchard, the question of varieties must be determined, first, by finding what varieties are well adapted to the locality in question. This can be learned by consulting the experiment station officials in the different States and from the experience of growers who have orchards in that locality. The next consideration is what varieties will meet the market demands and command the highest prices. It is a well-known fact that in the arid regions of the Pacific Northwest the Jonathan, Grimes Golden, Rome Beauty, Ben Davis, Winesap, and a few others are the best adapted to a commercial orchard; while in the humid sections of the same region the Newtown Pippin, Spitzenberg, and a few others have proven most successful. It might be well to note here, as has been stated before, that the Pewaukee and Ortley apples are always found worst infested with the codling moth, while the Lawyer and Winesap are least infested.

After it has been decided which varieties to plant, the next question is that of buying the stock. Good stock should always be insisted upon, and one can be sure of securing the desired varieties only by buying from well-established, conscientious nurserymen. It is preferable in the arid region of the Northwest to plant 1-year-old stock. The land usually has some vegetation upon it, such as sage brush or timber, and after clearing it the soil should be thoroughly pulverized. If irrigation is intended, the ground should be leveled and graded to facilitate irrigation. The courses of the irrigation ditches should be determined by the general contour of the land, taking into consideration the future routes of the spraying machine, which will draw upon these ditches for water for spraying.

SETTING THE TREES.

There are many methods which may be used for setting the trees, the details depending on the size of the orchard and the means at hand. The essential feature of the operation is to make the holes large enough to receive the roots of the tree, so that they can still retain their natural position. After filling and packing earth into the holes, water should be allowed to run in, to aid in giving the trees a good start.

It has been found that it is a very injurious practice to place any manure in the holes when the tree is planted. If manure is to be applied in the new orchard, the best method is to scatter it over the surface of the ground.

Care should be taken to cause the trees to lean toward the southwest, from which the hottest rays of the sun come. By doing so, sun scald will in a great measure be avoided. After sun scald the bark breaks, and the wood is exposed and becomes cracked and decayed. It has often been found that trees thus affected always bear a larger percentage of wormy apples than trees on which the bark is unbroken. This is accounted for by the fact that the codling moth larvæ go into the cracks to spin their cocoons and are there secure from their enemies.

It is a common sight in all sections of the country to see trees planted from 16 to 18 feet apart, with the upper branches intermingling so as to form a dense mass of branches which can not be sprayed properly, and there is no room between the rows for wagons or cultivators. It is strongly urged that the trees be set not closer than 30 feet apart; some growers prefer 40 feet.

PRUNING.

No arbitrary rules can be made for pruning on account of the fact that every kind of tree and plant, in fact every individual, presents its own peculiar problem; but there is an ideal which the pruner should endeavor to attain. It is found in many sections of the West that the trees have been allowed to fork so that there are two or three main branches, and upon bearing a heavy crop these branches have split apart, sometimes totally ruining the tree. At best, if the branches are brought back into place and held by bolts, wires, or ropes, a crack will be left, into which fungous diseases can enter and in which codling moth larvæ will spin their cocoons. Such a break should be dressed with grafting wax or shellac varnish, and the branches fastened closely together. With proper pruning, when the head of the tree is being formed, this trouble may be avoided. Instead of two or three main branches, the head of the tree should be so formed as to have four to six, thus distributing the weight, and preventing breakage under ordinary conditions.

Many apple growers have headed their trees too high for best results. The disadvantages of this method are that it is difficult to reach the fruit and foliage with spray, and much more difficult and expensive to harvest the fruit. Other growers have headed their trees so low that the branches spread and droop so that they are close to the ground. In many instances when there is a heavy crop of fruit these branches bend down and either touch or lie upon the ground. The result is that much of the fruit on the interior of these trees and on the under sides of the outer branches is so shaded by the foliage that the sunlight can not reach it, and a large percentage will be poorly colored and of second quality. (See Pl. IX.)

A mean between this high and low heading is to be desired, which will do away with most of the disadvantages of these extreme methods. In order to secure proper coloring in fruits on trees it is necessary that enough smaller branches be removed to admit an abundance of sunlight through the tops.

In the arid sections of the Far West the trees grow with great rapidity, and if allowed to take their natural course become slender and not strong enough to support a normal weight of fruit. It has been found that by cutting back half of each year's growth the trees will be made to grow heavier and stockier, and thus be able to support the weight of a large load of fruit without any danger of breaking.

IRRIGATION.

Proper irrigation of the orchard depends entirely upon the conditions. There are several methods of employing water in irrigation—by flooding, by a system of checks, or by furrows. The latter is probably the most efficient, but care should be taken that both sides of the tree receive an equal supply of water.

SOIL OR COVER CROPS.

The soil of different localities varies, and the treatment should vary with the conditions. In irrigated sections the soil is usually lacking in humus, and is often packed so closely together that it is impervious to water. By proper tillage this is corrected to some extent, but the greatest success has been attained by growing cover crops. Red clover is successfully used for this purpose, and is advantageous in many ways. The roots penetrate deeply into the soil, thus forming passages for water; by keeping a cover of clover over the soil, evaporation from the soil is retarded, and the irrigation need not be so frequent, as the water is retained for a longer time; the clover can be cut and used for hay; and about every third year the practice of plowing the clover is followed, so that, in addition to the fixing of nitrogen by the roots of the clover, the decaying vegetation adds needed humus to the soil.

ORCHARD IN BEARING.

A very serious error is made by many fruit growers in regard to the first crop of fruit. Reasoning that the first crop is not worth trying to save from the codling moth, the grower allows the insect to infest most of it, intending the following year to apply preventive and remedial measures and put it under control. The result usually is that the following year he has an abundance of insects, and his loss will be considerable. If, when the larvæ were all in this first crop, the apples had been destroyed by being picked and buried, or if bands had been used late in the summer, a large percentage of the loss in the second year could have been prevented.

It is often the case that on account of some unforeseen condition, such as a freeze or a frost, the fruit crop is reduced to almost nothing. Under such conditions each grower must decide for himself what methods he will pursue. Usually in such years the price of fruit is very high, tempting the grower to produce all the fruit he can, even if infested. The writer recommends that when the crop is so small that each tree will produce only about one box or less of good fruit, the fruit should be picked and destroyed, not earlier than the middle of July nor later than the middle of August, and other methods such as banding should be used to destroy as many of the remaining insects as possible. Various instances have been under the observation of the writer in which these suggestions were followed with great success.

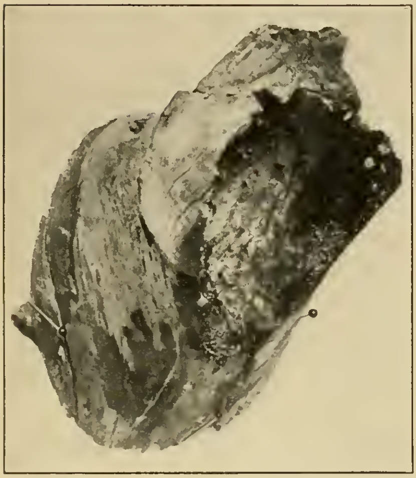


Fig. 1.

Fig. 2.

STUBS OF BRANCH CUT FROM A TREE, SHOWING WORK OF WOODPECKER.

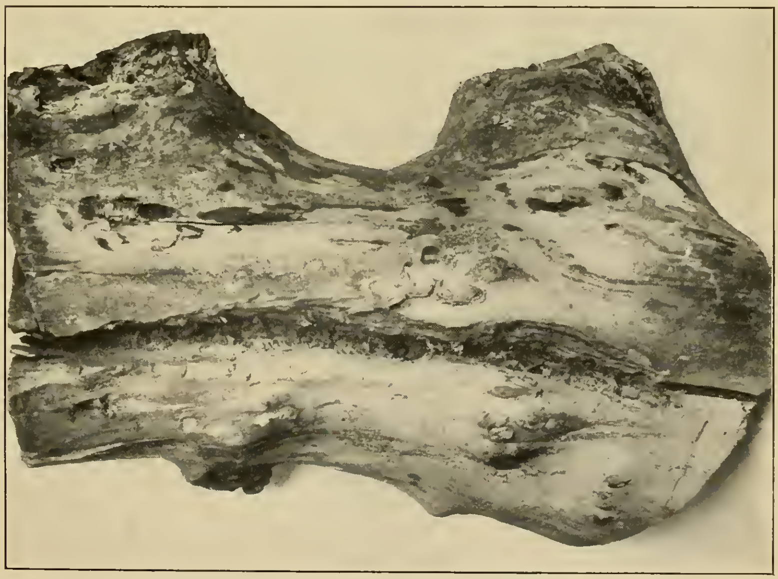
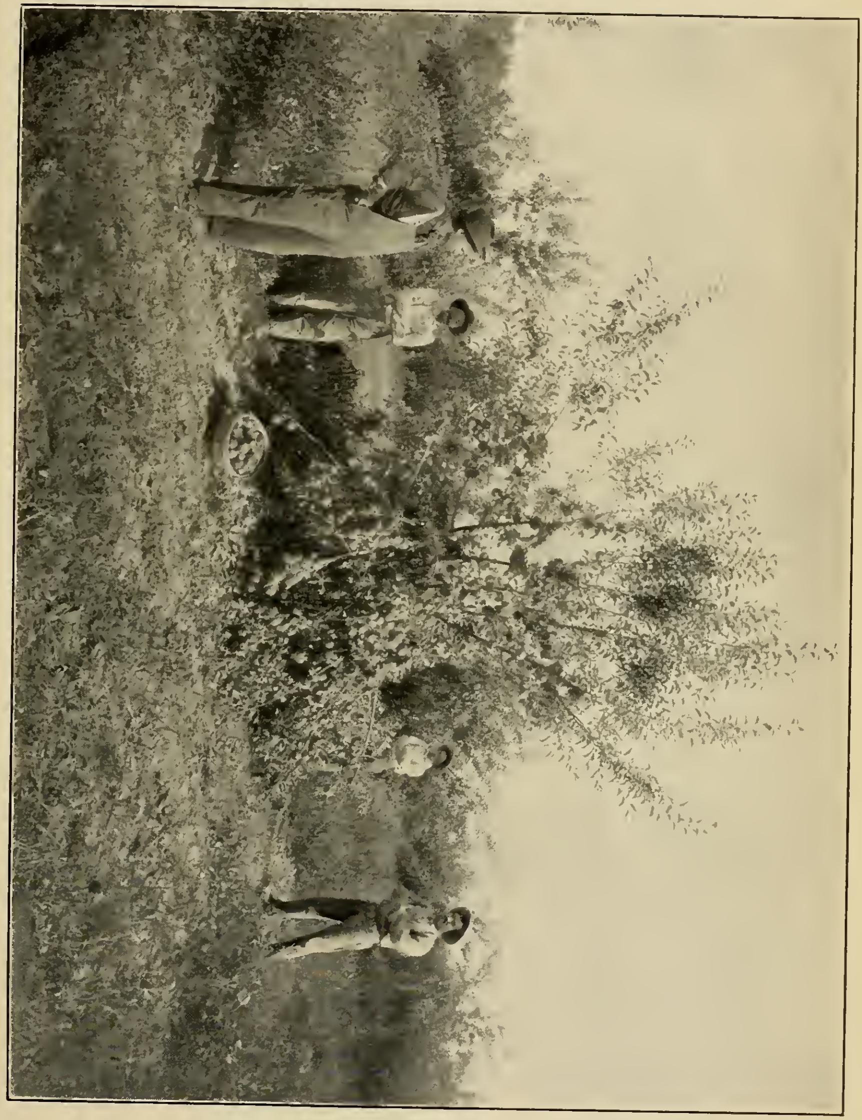


FIG. 3.—STUB ABOUT 8 INCHES LONG, SHOWING WORK OF CODLING MOTH LARVÆ AND WOODPECKER.

Twenty-eight moths which the woodpeckers did not get emerged from this piece of wood.

STUBS OF BRANCHES FROM AN OLD ORCHARD NEAR ELKTON, MD.



VIEW IN ORCHARD OF HON. FREMONT WOOD, NEAR BOISE, IDAHO.

Showing 8-year-old Jonathan tree heavily loaded with fruit. (From photograph.)

There are many preventive measures which may be applied to the orchard when it is in bearing.

It is a well-known fact that an orchard which produces a moderate crop each year is much more profitable than one which produces an abnormally large crop one season and a very small one the next. By thinning each year this alternation may be prevented to some extent.

The writer is very strongly of the opinion that if thinning is done when the larvæ of the first generation are in the fruit, and the fruit and larvæ destroyed, the advantages thereby gained are sufficient to compensate for the expense of thinning.

It is easy to see how the destruction of part of the first generation will prevent much of the injury due to the second generation, which is about ten times that by the first generation. It is difficult for the orchardist to determine by observing the entrance holes about what time the insects are inside the fruit. In thinning, all terminal clusters should be reduced to one fruit, and none should be allowed to grow closer together than from 4 to 6 inches. During the process of thinning, with but little increased expenditure of time or money, the wormy fruits can be removed and the perfect left on the tree.

Throughout the season a large number of fruits will drop from the tree to the ground. Upon examination it will be found that under normal conditions the larger percentage of these are the result of the work of the codling moth. The percentage varies, however, with many conditions. If a tree is heavily loaded, a large number of good fruits will be pushed off by those adjoining, and the wind will cause many to fall. The quantity of windfalls increases throughout the season.

The percentage of the larvæ to be found inside the wormy fruit varies with the time of the year. In the Pacific Northwest the latter part of June and the first part of July and the latter part of August are the times when the largest number of larvæ are found inside the wormy windfalls. In a small orchard these windfalls can be destroyed by allowing hogs to run at large in the orchard and eat the fallen apples; or the windfalls may be picked up every few days and either made into cider or destroyed. In a large commercial orchard, however, it is not probable that the expense of keeping the ground clear of windfalls would be justified by the benefits derived, although such benefits would undoubtedly be great.

PREPARING FRUIT FOR THE MARKET.

The method of packing which is now coming into use is to pack the fruit in the orchard, using packing tables built upon runners. These are hauled down a row, stopping at intervals. Two rows are picked on either side of the table, and the fruit is carried from the trees to the tables by the pickers. The fruit is there graded and packed, and the culls are left in piles in the orchard. The advantages of this method of packing are many. The fruit is handled but once, and is not hauled any distance until it has been securely packed, and the danger of breaking the skin or bruising is reduced to a minimum. The picking and packing crews also work as smaller units, and can be more easily directed and do far better work. The codling moth larvæ in the culls, after completing their development, will, if allowed to do so, spin their cocoons among the apples in the piles. (See Pl. XVI.)

Fruit may be well grown, well colored, and of proper varieties, but if not well packed these conditions are nullified. Apple growers in the Far West are confronted with rather special problems. By reason of their distance from the large markets of the United States, the price they would receive for second-quality fruit would hardly be sufficient to pay the expense of growing, packing, and shipping, and it is incumbent upon them to ship nothing except that which is strictly first class, packed in strictly first-class manner. The cost of transportation, prevailing market price, and size of crop, however, must be taken into consideration.

The methods of packing depend upon the kind of package used. Eastern grown apples are usually packed in barrels. From Colorado and Montana westward boxes containing either 40 or 50 pounds are almost universally used. Some are even going further, using small packages containing half bushels of superior fruit. There are many methods of packing the fruit in these boxes, as may be required by the purchasing dealers. In all cases it is highly essential that the fruit be packed so tightly in the box that there can be no shifting of position while in transit; that there be a decided swell in the boxes on both top and bottom if they are made of thin and flexible wood, as is usually the case in the West; that the paper lining of the box remain unbroken, and that when the fruit is opened it will be attractive to the buyer.

The more progressive fruit grower is well aware of the fact that a reputation for first-class fruit can be obtained and secured only by packing such fruit and rigorously excluding all wormy or scale-infested apples. Although it is extremely difficult for a packer to put up a box of apples containing not a single wormy fruit, it should be firmly impressed upon his mind that is the ideal to be attained.

The second-quality apples, which are usually disposed of in the local markets, are those but slightly injured by the codling moth, or undersized or uncolored. The culls and windfalls should be piled together and disposed of as quickly as possible. They may be either fed to stock immediately or made into cider for vinegar. The value of these culls is considerable, and progressive orchardists count a good deal on the revenue derived from them. From the seconds, culls, and windfalls in one orchard with which the writer is familiar

5,000 gallons of cider were made, which sold for as high as 20 cents per gallon. One bushel of apples made from 2½ to 3½ gallons of cider, by means of a hydraulic press run by the gasoline engine used in spraying.

If it is not possible to dispose of the culls otherwise, they should be buried in holes in the orchard and covered over with 6 to 8 inches of closely packed earth. (Pl. VI, fig. 2.) Occasions may arise when it is necessary to store these for some time, although the storing of such fruit should be avoided if possible.

Fruit should be stored in a house in which there are no holes or cracks in the roof or walls. When the larvæ inside the fruit have completed their development they spin cocoons and transform into pupæ, which in turn transform into moths. These moths emerge, and if there are cracks or holes in the house they will escape and fly to the orchard the following spring. If, however, the house is tight it may be fumigated; or, better still, screens may be placed over the windows, and as the moths collect upon these screens, they may be crushed, or they will die if left a week or so.

The writer studied two cases in Idaho in which apples were stored quite near an orchard. (Pl. IV, figs. 2 and 3.) The effect was that the following year the part of the orchard nearest the apple house was always most infested, and in spite of all the remedial measures applied there was a great amount of damage. In California it was found by Mr. De Long that in a house in which apples were stored the moths always emerged and went to the windows. Records were kept of these insects, and it was found that 11,974 moths were killed from April 15 to August 12. One can easily imagine what destruction these moths would have caused had they been allowed to fly to the orchard.

PREVENTIVE MEASURES IN OLD ORCHARDS.

In all sections of the country old neglected orchards are easily found in which practically all of the fruit is infested by the codling moth. The writer is quite familiar with two typical orchards, one of which is situated in an irrigated section of the far West and the other in a humid section of the East. Although the climatic and other conditions are quite different the two orchards have many features in common.

The western orchard consists of about 300 trees about 18 or 20 years old, planted about 16 feet apart each way. The branches of each tree touch those of the surrounding trees so as to form a dense mass of branches and foliage. The former owner of the orchard, finding that the codling moth destroyed the larger part of the fruit, gave the orchard no irrigation, and in consequence the trees are in a more or less stunted condition. The branches are thickly matted together, having never been pruned. The trunks and branches of the trees are covered with rough scales of bark, and where branches have been cut away the stubs remain, with irregular cut ends, the branches having been hacked off with an ax. These stubs have in many places cracked and begun to decay, thus making excellent places in which the larvæ of the codling moth could spin their cocoons and hibernate. The writer once secured 20 larvæ from the holes and cracks in one of these stubs. The cut ends were not given proper dressing and decay has taken place, often leaving large holes in the trunks and branches. Many cocoons can be found in this rotten wood, and on all the trunks and branches one can find numerous empty pupal skins from which moths have emerged. The soil of the orchard has received no cultivation and is covered partly with weeds, principally prickly lettuce. The orchard is very productive and always bears a good quantity of fruit, but, being undersized and from 90 to 98 per cent infested by the codling moth, practically no revenue has been derived from it for the past five or six years. In 1900, 1901, and 1902 the writer searched carefully for uninfested fruit, and each time found on the tree near the trunk only a dozen or so small stunted apples which had escaped the codling moth. Other insect pests are present in this orchard, each requiring special treatment.

The eastern orchard is situated in a good horticultural region. The trees number about 300, and are probably about twenty-five years old. They are placed 40 feet apart, and have made a good growth. The trees have received some pruning, but as in the western orchard there are many stubs left, and there are numerous decayed holes in the trunks and branches. In many trees the branches are matted together and shade the fruit. The soil is in fairly good condition and lightly sodded. Until the past two or three years the orchard has been remarkable for its productiveness, but a large percentage of the fruit was small and much the larger part of it was infested with the larvæ of the codling moth.

The treatment that these orchards should receive to bring the codling moth under control is about the same. It may be stated that if the preventive measures advised for a young orchard had been faithfully and intelligently carried out many of the existing conditions would not have been present.

TREATMENT OF OLD ORCHARDS.

The first thing to be done to old orchards is to prune the trees in such a manner that the sunlight and spraying solutions will have easy access to the foliage and fruit. Every other tree in the western orchard should be cut down. The stubs of branches should be sawed off close to the trunks and burned in order to destroy the hibernating larvæ contained in them, and the cut ends remaining on the tree covered with shellac varnish or grafting wax. The holes in the trunks and branches should be filled with cement, plaster, or clay, in order that the insects inside may be confined and die, and that other larvæ later in the season will be unable to enter to spin their cocoons. The rough bark on the trunks and branches should be scraped away and burned.

In both of these orchards it is a noticeable fact that the woodpeckers have been very efficient in digging out the hibernating larvæ. (Pl. VIII.) It has been often noted by authors that early in the spring it is almost impossible to find larvæ of the codling moth under the rough bark and other exposed places in badly infested orchards. Instead of finding the cocoons with the larvæ inside, one will find empty cocoons with a hole through the bark of the tree, showing that the insect has fallen prey to woodpeckers. All places in which the larvæ might spin cocoons should be destroyed or rendered unsuitable, and the larvæ forced to spin cocoons in exposed places where the woodpeckers and other birds can get them.

The soil in these two orchards should receive about the same treatment, except that irrigation should be begun in the western orchard. They should both receive a very shallow cultivation for about one year, with a dressing of manure. The cultivation should be so shallow as not to injure any of the roots, which may be quite near the surface. The second year, red clover, cowpeas, or some other leguminous cover crop should be sown, and every third year this may be turned under, thus adding available plant food to the soil. When these methods are followed the recommendation given for an orchard in bearing should be adopted. At best the preventive measures can not control the insect in an orchard, but they are valuable adjuncts which render the measures more efficient.

REMEDIAL MEASURES.

Remedial measures against the codling moth are those measures from which little or no benefit is derived except in saving fruit from the ravages of the insect by killing it.

MEASURES OF LITTLE OR NO VALUE.

The codling moth seems to have been common in orchards for many centuries, but no one made any suggestions as to how its ravages might be checked. The first recommendations made were of no value, and it is interesting to note how these recommendations have recurred at various periods in popular writings. Many of these remedies, having little or no value, are taken up by companies, given all the benefit of modern advertising methods, and thoroughly distributed before the fruit growers become aware of their worthlessness. In order that the fruit grower may know what not to do as well as what he should do, a number of the more prominent of these inefficient methods are briefly discussed.

It has often been recommended that moth balls be hung in the trees in order to keep the moths away. If there were any virtue in this remedy, so many of the moth balls would have to be hung on each tree, to do the work, that the expense would render it valueless.

Smudging the orchard, or burning ill-smelling compounds so that the fumes will pass through the trees, has been practiced to some extent. The theory is that the moths will be kept away by the fumes and go to other orchards to deposit their eggs. It is quite evident that as soon as these fumes are blown out of the orchard the moths will return if they have left, and in order to produce any results it will be necessary that the smudge be continued practically throughout the season.

Plugging trees with sulphur or other compounds and plugging the roots with calomel have been practiced to some extent, on the theory that the sulphur or calomel will be taken up by the sap, distributed through the tree, and prove distasteful or poisonous to the insect. Trustworthy scientific experiments have been carried on which show that it is absolutely impossible for the tree to take up any amount of these substances, and little or no effect upon the insects results.

The writer has found several orchards in which the trees were banded with tarred paper, the evident intention being to keep the larvæ from getting up into the trees. Knowing the habits of the insect when in its larval form, we can see that this method is ridiculous, and instead of being a detriment it is a positive aid to the insect; in many cases larvæ were found which had spun cocoons under the bands, which formed a place in which they were comparatively free from the attacks of their enemies.

There seems to be a popular idea among many farmers and fruit growers that all insects are attracted to light. Based upon this idea, there have been many recommendations to keep fires burning in the orchards, or to arrange some sort of a trap lantern by which the insects are to be attracted to the lights and fall into water on which is a film of kerosene and thus be killed. This scheme of trap lanterns was exploded many years ago, but it seems that at intervals somebody revives it, and its fallacy must be exposed afresh. By carefully experimenting with trap lanterns and determining the catch as accurately as possible it is found that the majority of the insects caught are either decidedly beneficial varieties, or are males, or females which have already deposited their eggs, and that but few injurious insects are caught, and none in any great number. Probably the most extensive experiments with trap lanterns were those conducted by Professor Slingerland. Among 13,000 insects he was not able to recognize a single codling moth. This is the usual result of all these experiments, and we can say without any hesitancy whatever that the farmer who uses these trap lanterns or tries to experiment with them is simply wasting his time and money, as the method has been thoroughly proven ineffective.

It is also the practice to some extent to put cans or bottles containing molasses, cider, vinegar, or some other substance of similar nature in the orchard, and upon finding that insects are attracted by these compounds and killed, many fruit growers think this is a good remedy for the codling moth. The results of many careful experiments show that only incidental captures of the codling moth are made. With both these last two practices—that is, trap lanterns and baiting the moths—the greatest trouble has been that the fruit growers are not acquainted with the codling moth in its early stages. Any fruit grower can breed moths for himself, and by comparing his catch can very easily satisfy himself.

Many times fruit growers have tried spraying their orchards with ill-smelling compounds with but little success. These compounds are always more or less expensive and have never been so efficient as to justify their use.

Other fruit growers think that spraying the orchard with water frequently will give relief from the attacks of the codling moth. Undoubtedly if the trees were kept in a spray all the time, the fruit would be clear of the insect; but if this were done, the probabilities are that no fruit would set, and if any should set it would not ripen well, and the trees themselves would probably die. The expense of this operation would be many times greater than that of spraying.

It has been stated that electric lights repel the moth and that trees near electric lights in cities are often free from its work. The writer had an excellent opportunity to investigate this point, and found that an apple tree about 40 feet from an electric light was as badly infested as any other in that vicinity.

In order to do away with the labor entailed by using bands around the trees many kinds of traps have been invented. Riley, by careful experiments, showed that one of these traps would not catch as many larvæ as the bands; and other experiments have shown that these patent traps are never very efficient.

It was claimed for some time that the flowers of plants of the genus *Physianthus* might be efficient against this insect, since in order to reach the honey of the flower the proboscis would have to be passed through a narrow cleft, from which it could not be withdrawn, and the moth would therefore be held a prisoner until it died. It was proposed to train the vines around the trunks and branches of the trees, and, the moths being captured, the orchard would be protected. Conclusive evidence has been recorded which shows that these flowers have no attraction for the codling moth.

It has been suggested that the codling moth might be controlled by bacterial and fungous diseases. From the facts that the insect leads such a protected life and that fungi and bacteria have given so few positive results in this connection it is almost useless, with our present knowledge, to even theorize upon the value of these agencies.

In general it may be stated that entomologists have at all times tried experiments with these different plans and are unanimous in their conclusions. If anything new and efficient is ever perfected by which this insect may be more easily controlled, no doubt entomologists will be its first advocates.

MEASURES OF VALUE.

By taking into consideration all the habits and variations of habits of the codling moth in its different stages we find that, like other insects, there are certain stages in its life history in which it is more amenable to remedial measures than at others. We find that it can be best attacked in the larval stage, although some experiments indicate that something can be done when it is in the egg stage. Cook found that by spraying an apple tree weekly from May 15 until the end of June with a strong soap solution he succeeded in preventing the infestation of a single apple by the larvæ. In laboratory experiments with kerosene emulsion Card secured good results against the eggs. Gillette also obtained good results with kerosene emulsion. The results of these experiments have never been put to practical use for many reasons. The kerosene emulsion would probably be so strong, in order to have any effect on the egg, that it might injure the tree. The kerosene would evaporate quickly, and thus its effect would be for but a short time. The expensiveness of kerosene in the West, and the number of times the spraying would have to be made to be efficient, would prohibit the adoption of this method. The insect can be more easily attacked, at less expense and with greater effectiveness, in the larval stage.

MEASURES USED AGAINST THE LARVA.

The remedial measures used against the larva vary according to whether they are used after it has been hatched and before or while it is entering the apple or after it has completed its growth and left the fruit. The greater effectiveness is secured by the use of arsenical sprays before the larva has entered the fruit. The effectiveness of these arsenical sprays against the codling moth was discovered by accident in 1872. Le Baron recommended the spraying of trees with Paris green to check the ravages of the cankerworm, which recommendation was adopted in many orchards with great success. Professor Slingerland states that the credit of this discovery belongs to Mr. E. P. Haynes and Mr. J. S. Woodward, who found that spraying with

Paris green not only rid the orchard of cankerworms, but that the apples on the sprayed part were much less affected by the codling moth. It seems that other people used Paris green for cankerworms in Iowa, but there are no indications that they were alive to the fact that at the same time they were checking the codling moth. Prof. A. J. Cook, of Michigan, took up the idea and by a series of careful experiments clearly showed that the treatment was very effective against the codling moth. Forbes, Goff, and numerous others have at various times carried on spraying experiments with arsenicals, with results that show this to be the most effective and cheapest remedial measure that can be used.

SPRAYING.

Spraying with arsenicals may be defined as putting a coat of any arsenical poison on the foliage and fruit of a tree, so that when the insects eat the foliage or enter the apples they eat some of this poison in their first few meals and are killed. Since the beginning of the practice of spraying there have been many important improvements in both spraying machinery and spraying solutions, which have rendered the process much easier than when primitive methods were in vogue.

SPRAYING MACHINERY.

There are as many kinds of spraying machinery as there are conditions to be met in spraying operations. There are certain spraying outfits devised especially for orchard work, varying from the common bucket pump to rather complicated machinery driven by gasoline engines. For a small home orchard or for an orchard of a thousand trees or less the writer would advise the use of a hand-power outfit. The capacity and cost will depend primarily upon the size of the orchard, the size of the trees, and the rapidity with which it is desired to spray the orchard. There are many excellent types of spray pumps on the market, and no mistake can be made in selecting any of the outfits of the better manufacturers, but there are several points which should be insisted upon. The interior fittings of the pump should be of brass and should be arranged so that the inside of the cylinder can be easily reached in order that repairs may be made. The air chamber, which insures a steadier stream and acts as a reservoir of force, is almost a necessity. A pressure gauge upon this air chamber will be of great value, as it will aid the man who does the pumping to keep the pressure at about the same point. The pump may be mounted upon a barrel, which may be stood on end or put on the side, or it may be mounted on a tank or upon the wagon frame on which the tank is mounted. These tanks are preferably of wood, and should be of very strong construction and securely bolted together with iron rods. Screens should be used to strain out particles which would clog the nozzles, and should be used both as the water is put into the tank and as it is pumped out. It is highly essential that some mechanical device be used to keep the liquid in agitation so that the coarser particles will not settle to the bottom of the tank and render the mixture of variable strength, especially if Paris green is used. The hose may be any of the types in use, and a hose extension of some light tube, covered preferably with bamboo, should be used in order that the tops of the tall trees may be easily reached. A stopcock at the junction of the hose and extension can be used to great advantage.

The nozzles most used in spraying orchards are of two types—those which throw a fan-shaped spray, which are used for long-range work, and those which throw a cone-shaped spray, which are used for close work. Several of these nozzles may be placed on one bamboo extension, and thus the amount of liquid thrown increased. Four lines of hose may run from one pump, but it is found that so large a number causes confusion and that more work can be done with two lines of hose. The usual number of nozzles upon each extension or line of hose is two. The nozzles can be set at an angle to the axis of extension, and then by turning the extension the stream can be variably directed. If the spraying outfit is small, consisting of a barrel with a pump, it can easily be hauled through the orchard on a sled; but if the outfit is larger it is usually drawn upon an ordinary wagon. Details of the mounting on the wagon and the position of the pump and tanks will depend a great deal upon the facilities which the grower has at hand. Many have the tanks and pumps mounted upon a frame, which they can put upon the wagons and remove when the spraying is completed. If it is desired to spray very tall trees, it has been found that spraying can be done more rapidly and thoroughly if there are high platforms built upon the wagons upon which the operators can stand (fig. 17). The capacity of these hand-power spraying outfits depends upon many factors, such as the number of men employed, size of pump, number of nozzles, capacity of tank, distance from water supply, and size of trees. It has been found that three men, using a 200-gallon tank and two lines of hose, each fitted with two nozzles, can spray about 250 average-sized trees per day. These hand-power spraying outfits can be purchased and put in working order for from $15 to $75. A pump, if used for arsenicals alone and given good care, should last for five or six years with but few repairs. But if the same pump is used for spraying with the lime, sulphur, and salt compound, and the compound allowed to corrode the pump, it will be necessary to purchase a new pump oftener. (See Pls. XI and XII.)

GASOLINE-POWER SPRAYING OUTFITS.

If an orchard consists of more than a thousand trees, it will be found expedient to use a gasoline-power spraying outfit. If the orchard consists of five to ten thousand trees, it will be found that the expense per tree with this outfit is only about half of what it would be with hand-power sprayers.

Many dealers have placed spraying machines on the market in which the power is derived from gasoline engines. They consist largely of engines, pumps, and machinery for other uses, placed together for this purpose. While a majority of these are quite well adapted to the work of spraying, many improvements are possible which would

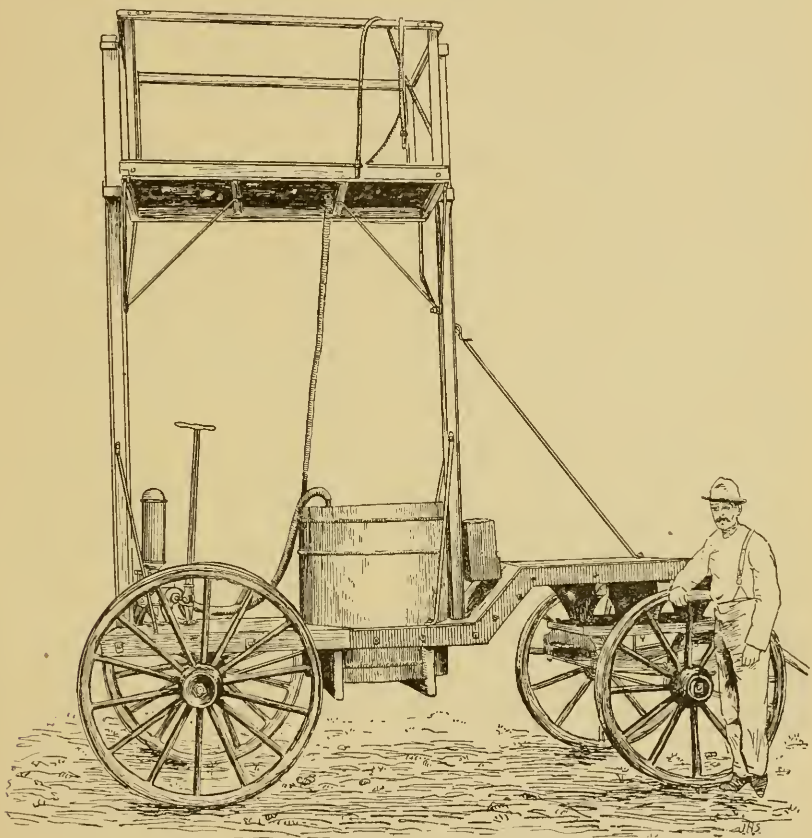


FIG. 17.—Spraying outfit for treating tall trees (after Gould).

increase efficiency without increasing cost. There are many makes of gasoline engines, most of which are well adapted to this work. The horsepower of the engines is usually too large. An outfit with which the writer is most familiar is run by a 1½-horsepower gasoline engine, and in ordinary spraying operations it was found that the engine was too powerful, as four out of nine possible explosions were all that was required to run the pumps and keep the pressure at 100 pounds. The engine for spraying purposes should be about 1 horsepower, which may be more than is required at ordinary times, but occasions may arise when more power would be desired.

There are many methods by which gasoline is fed into the cylinders of these engines. The better engines have a pump by which the gasoline is forced into the cylinder. The ignition is accomplished by one of two methods—either by an ignition burner on the outside of the cylinder which communicates heat to a platinum point which explodes the gasoline vapor, or by an electric spark from an induction coil which is connected with numerous dry batteries. The cooling tank used with these engines for the purpose of keeping the cylinder moist and cool is usually from 12 to 14 inches in diameter. This size is intended for stationary engines, where the water can not be renewed frequently. In spraying, however, the water can be renewed every few hours if necessary; and therefore the tanks can be built as small as 6 inches in diameter, which will make a considerable reduction in the weight of the machinery.

Purchasers are always given full instructions in regard to the care and running of these engines, so that one with comparatively little mechanical ingenuity has very little trouble. The greatest source of difficulty is with the electric current. The insulations often become imperfect or the sparking points become dirty and fail to produce a spark. By carefully testing the current and keeping these points clean practically all of the trouble is avoided.

It is preferable to place the engine at the rear end of the frame and the pump as near the engine as possible. There are two types of spraying pumps which may be used for this purpose—the triplex pump, which consists of three vertical plungers, and the straight horizontal double-acting force pump. Either of these pumps will be found to answer to the conditions required for these outfits, but the horizontal pump is more commonly used. The pumps should be so manufactured that all of the parts are accessible and the brass lining easily removed. The working parts should be made of brass or bronze. A large air chamber is essential, as well as a pressure gauge. It is absolutely necessary that a relief valve be attached to the pump, so that when the stopcocks on the bamboo extension are closed the engine will not have to be stopped, but at a certain pressure the spraying liquid will be returned to the tank.

In sections of the country where irrigation is practiced it has been found that the most effective method of filling the tank is to have another pump which can be attached to the engine, by which water can be pumped from an irrigating ditch into the tank. This pump should belong to the type known as "low-down pumps," which deliver large quantities of water at low pressure. The suction hose should be 2 or 3 inches in diameter and the end which is put into the irrigating ditch should be w 'l screened. There is usually some method by which this pump can be connected with the engine. It is unnecessary to disconnect the spraying pump from the engine, as the suction hose of the spray pump may be removed from the spraying tank. This filling pump and connections can be purchased for about $20, and the time and labor saved by its use will pay for it many times over during the season. This idea of having a filling pump attached to the spraying machine was originated and carried out successfully by Hon. Edgar Wilson, of Boise, Idaho.

As before stated in regard to hand-power outfits, it is found much more expedient to use only two lines of hose. The length of this hose will depend upon the method used in spraying the trees. Bamboo extensions and nozzles are the same as those used in power outfits. It is found that water from irrigating ditches contains a considerable amount of sand. The effect of the sand and the lime in the spraying solution is to cause the face of the nozzle to become badly worn, rendering it unfit for use in five or six days of continuous spraying. Letters have been written to the more important manufacturers calling their attention to the fact that if these faces were hardened or made of steel the nozzles would last much longer, and it may be that these firms will shortly put such improved nozzles on the market.

The tanks used in these spraying outfits may be made of wood or galvanized iron. The latter would be preferable on account of its lightness, but it would be disadvantageous because it would be somewhat difficult to thoroughly brace it. The tanks should not have a larger capacity than 150 gallons and should be placed on the front end of the frame. Screens should be placed over the end of the hose leading from the filling pump, as well as over the suction hose from the spraying pump.

The agitator which has given the best satisfaction in this connection is formed by two paddles set at an angle, mounted on a vertical shaft, and run by power derived from the gasoline engine by means of a belt and bevel gearing. This agitator keeps the spraying solution in violent agitation and renders it uniform.

The whole machine, engine, pumps, and tank should be mounted upon a rigid frame. On this frame there should be a platform at either side, with a railing, upon which the operators can stand. There should be supports for the bamboo extensions placed near the center of the outfit. (Pl. XI, fig. 2.) This frame can be mounted upon an ordinary wagon, but it is preferable to use a low wagon with steel wheels and tires not less than 6 inches in width, which will largely prevent the wheels from sinking into the soft earth. A team and two men are required to operate this outfit. Both of the men spray; one drives, and the other starts and stops the engine. This reduction of labor makes a material reduction in the cost of spraying.

Many tests have been made of these machines working under actual conditions, and it is found that 700 trees (in the West, where they are considerably larger than trees of the same age in the East) can be easily sprayed in one day. Some fruit growers tell the writer that they have been able, when they found it necessary to work more rapidly, to spray 900 trees per day. By a series of observations it has been found that it takes from four to five minutes to fill the tank by means of the filling pump, and the same amount of liquid can be sprayed out in from thirty to forty minutes, upon from 60 to 80 trees, depending on their size, using about 2½ gallons per tree. In an irrigated orchard it is quite desirable that the ground be allowed to become dry before the spraying is begun, and thus avoid miring the machine in the soft earth, which will frequently occur in wet places in the orchard, especially when the tank is full.

The cost of these complete machines varies with the cost of the engine and pump and their fittings. They can be purchased for from about $260 to $500. The machine with which the writer is most familiar cost $320, which included a $40 wagon and filling pump and attachments at $20. With good care and proper repairs these machines can be made to last for several years. In a working day of ten hours it was found that a 1½-horsepower engine consumed about 1 gallon of gasoline. Although the initial expense of this outfit is greater than that of the hand-power outfit, it will be found to be much cheaper in the end, as the engine can be made to more than pay for itself by other uses when spraying is not in progress, such as running the cider press, feed cutter, and cream separator, sawing wood, turning the grindstone, and numerous other tasks about a farm for which power is desired. The machinery can also be removed from the wagon and stored in an outhouse and the wagon used for other purposes.

WATER SUPPLY.

The distance of the water supply from the orchard is one of the greatest factors in determining the rapidity with which spraying can be done. With the water supply some distance away much valuable time is lost in going to and fro to fill the tank. In the smaller orchards, where but little spraying is done, the usual custom is to drive the wagon to a ditch, pool, or well, where the water is transferred into the spraying tank with buckets. Many fruit growers have found it advantageous to draw their supply of water from an elevated tank into which water is pumped by a windmill or piped from some spring or stream. For irrigated orchards the water is usually taken direct from the irrigating ditches, sometimes from the main ditch and sometimes from the lateral ditches running through the orchard. By taking the water from these laterals in the orchard the routes of the spraying apparatus in operation can be largely determined, the foreman trying at all times to be near one of them when the tank becomes empty. By means of the filling pump on the gasoline power outfits much valuable time can be saved in the operation of filling the tank, as compared with the method of having an extra wagon to haul water to the spraying outfit, sometimes employed. The routes followed by the spraying machine in the orchard depend upon many factors, such as source of water supply, position of hills and ridges, and direction of wind. Each orchard is a problem by itself, and experience will show which routes can be followed with the least loss of time.

APPLICATION OF SPRAY.

There are many methods of spraying the trees. In following the chosen route through the orchard some use four lines of hose, completely spraying four rows of trees at a time; but it has been found in actual practice that on account of the long hose and the great distances the men have to walk other methods are more advantageous. Many use two lines of hose, and men standing on the ground go completely around the trees, thus spraying two rows on all sides. Other fruit growers drive down one row and spray half of the tree on either side; coming back on the other side of the row they spray the other side and one-half of the next row. It has been clearly shown that this method gives the best results, both in the saving of time and in completely covering the trees. When the trees are tall it is quite necessary that the men ride upon an elevated platform, and it has also been found advantageous in using the gasoline-power outfit to have the men ride on the apparatus. In this way not only the men are saved unnecessary labor, but from their elevated position they can spray the trees more thoroughly. With the nozzles set at an angle on the bamboo extension, part of the tree can be sprayed as it is being approached. Then on stopping at the tree the whole side can be sprayed, and when leaving it the last part can be sprayed and spraying be begun on the next tree. It is almost impossible to spray while moving at right angles to a strong wind, and if such a wind is encountered it will be found desirable to have the wagon go either with or against it and take advantage of it by allowing it to blow the mist through the trees. Experience on the part of the operators will enable them to devise methods to reduce the time without impairing the effectiveness of the spraying.

The ideal to be attained in applying spray is to cover the tree with a thin coating of the spray solution, so that when the water dries it will leave a coating of poison on every portion of the foliage and fruit. When the spray is applied with but little force the stream does not break up into sufficiently fine globules, and when they strike the foliage they either cover only a small portion of it or run together into large drops and fall to the ground, leaving but little of the solution on the tree, and that little very much scattered. If, however, the spray is applied with great force, the stream is broken up into a fine mist, which, if well directed, is evenly distributed over the foliage and fruit, and upon drying leaves a more or less uniform coat. If the nozzle is held close to the foliage, the force causes it to spread well, but the coating is not so uniform as that which is derived from the mist. In spraying one-half of a tree the mist drifts through the tree from the side which is being sprayed, and in that way the tree is well covered, having received practically two incomplete sprayings. If fruit is allowed to grow in clusters it is necessary to apply the spray with great force in order to secure good results.

MATERIALS FOR SPRAYING.

CONTACT INSECTICIDES.

Contact insecticides are those which kill the insects by touching them. Kerosene emulsion and solutions of whale-oil soap are the substances that have been most used for this purpose; but on account of the expense, the necessity of frequent application, and the fact that the insect can be more easily and effectively reached in other stages by other insecticides, these kinds of spraying solutions have been used but little against the insect.

ARSENICAL SPRAYS.

The arsenical sprays contain arsenic as their essential ingredient. Other chemicals are mixed with the arsenic for the purpose of preventing it from burning the foliage or are products incidental to the numerous compounds of arsenic which were used for other purposes than spraying. There are many spraying compounds of which arsenic is the base on the market, but there are many others which the fruit grower can make for himself by combining the necessary ingredients.

Paris green is probably the best known of these arsenicals. It has been used for many years with success, and is a definite chemical compound of arsenic, copper, and acetic acid. The composition is usually quite uniform, but many instances have been found in which it was adulterated or the percentage of soluble arsenic was dangerously high. As indicated by its name, it is a substance green in color. It is a rather coarse powder, which has the fault of settling rapidly in the spraying tank. It is quite necessary to use lime with Paris green in order to counteract the burning effects of the free arsenic. Paris green is comparatively expensive; in the East it costs about 20 cents a pound and in the West 25 cents.

Paris green may be prepared for spraying as follows:

Paris green	pound	1
Lime	pounds	1 to 2
Water	gallons	100 to 250

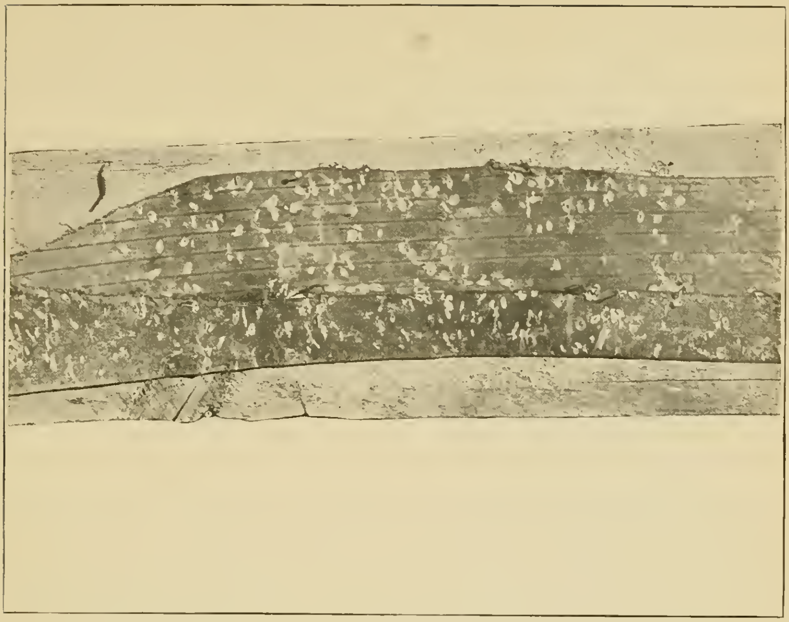


FIG. 1.—BAND ON WHICH THE REMAINS OF 330 COCOONS WERE COUNTED.

FIG. 2.—PUPA IN COCOON ON UNDERSIDE OF A LOOSE PIECE OF BARK.

FIG. 3.—LARVA AND PUPÆ IN CRACKS IN BARK, FROM WHICH ROUGH BARK HAS BEEN REMOVED.

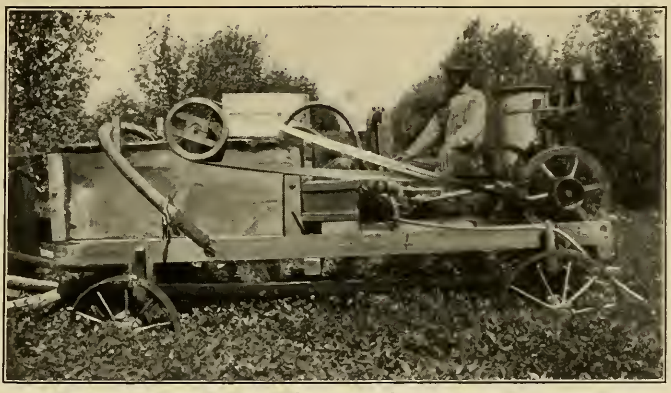


FIG. 1.—GASOLINE-POWER SPRAYER, SHOWING THE ENGINE AND SPRAY PUMP.

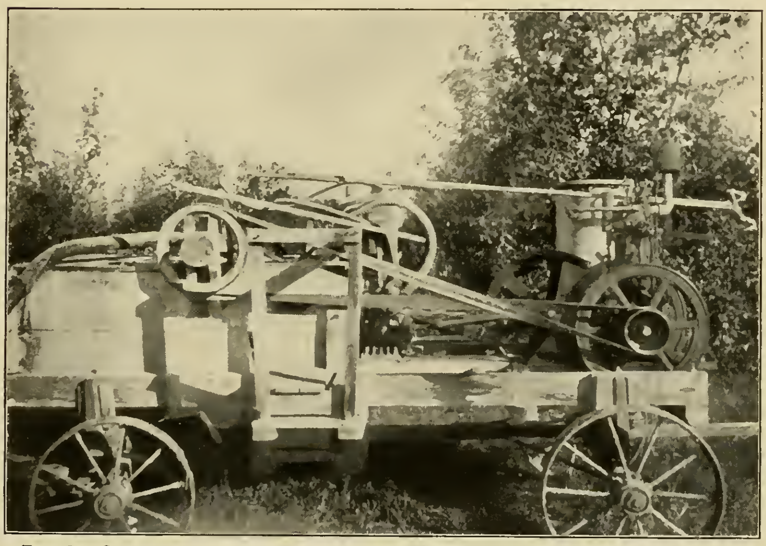


FIG. 2.—GASOLINE-POWER SPRAYER AS IT WAS IMPROVED DURING THE SEASON.

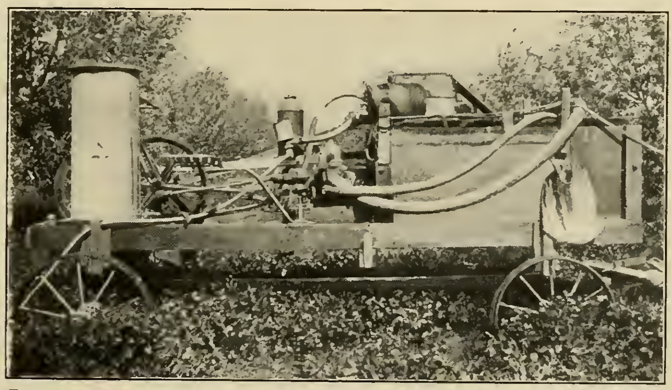


FIG. 3.—SAME SPRAYER AS IN FIG. 1, BUT SEEN FROM THE OTHER SIDE, SHOWING FILLING PUMP AND ATTACHMENTS.

GASOLINE-POWER SPRAYING MACHINES.

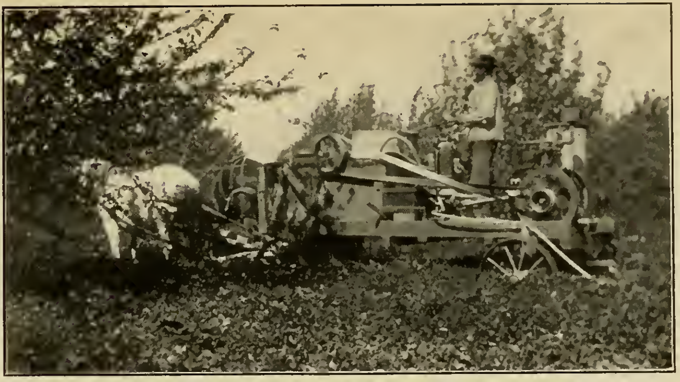


FIG. 1.—GASOLINE-POWER OUTFIT IN THE ORCHARD.

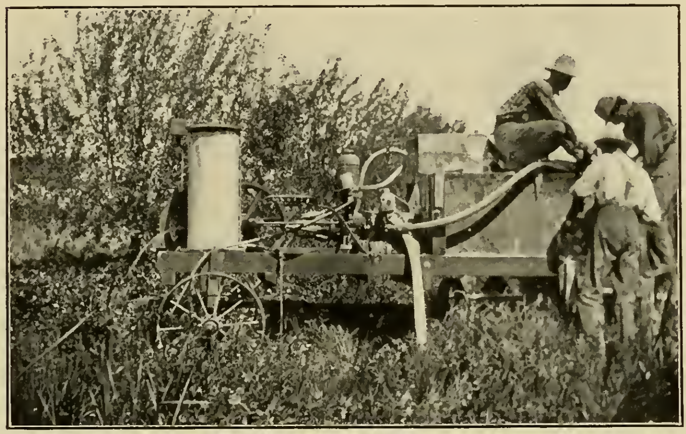


FIG. 2.—FILLING TANK BY MEANS OF THE FILLING PUMP FROM AN IRRIGATION DITCH.

FIG. 3.—HAND-POWER SPRAYING OUTFIT, IN WHICH THE PUMP IS MOUNTED UPON A BARREL ON AN ORDINARY WAGON.

SPRAYING OUTFITS IN USE.

The lime should be fresh and slaked in small quantities as needed. By mixing a small quantity of water with the Paris green until a paste is formed it is much more easily distributed in the water. The lime may be added to the water in the proper quantity.

A good average strength of this solution is 1 pound of Paris green to 150 gallons of water; but for trees with delicate foliage, such as peach, it is advisable to use a much weaker solution. Many fruit growers are using Paris green of the strength of 1 pound to 100 gallons, with the addition of lime upon apple trees, without burning the foliage.

Scheele's green is a similar preparation to Paris green, but differs from it in lacking the acetic acid. It is a finer powder than Paris green, is much more easily kept in suspension, and the cost is only about half that of Paris green. There is but little of this insecticide manufactured and placed upon the market.

London purple is a waste product in the manufacture of aniline dyes. It contains a number of substances, of which the principal ones are arsenic and lime. It is quite variable in composition, and is generally considered as being not so effective as some of the other arsenicals. For spraying it is now being replaced by the other poisons.

Both Scheele's green and London purple are prepared for use in spraying similarly to Paris green.

WHITE ARSENIC COMPOUNDS.

If white arsenic is used alone in spraying, it will seriously injure the foliage of the trees by burning, but when combined with other chemicals which prevent this burning, it forms the base of our most effective sprays, any of which can be easily prepared by the fruit grower.

Arsenite of lime.

White arsenic	pound	1
Lime	pounds	2
Water	gallon	1

The white arsenic and the lime are boiled together for not less than half an hour in the required amount of water, as it is very difficult to make the lime and arsenic combine. After the combination is complete enough water is poured in to replace that lost by evaporation. This solution may be kept as stock, and 1 pint of it used to every 40 or 50 gallons of water. It is advisable to add more lime to this spraying solution in order that all danger of burning may be avoided. Although this solution is by far the cheapest spraying material, there is much danger of poor combination of the arsenic and lime, leaving free arsenic, which will injure the foliage. In order that the lime may more thoroughly combine with the arsenic, soda has been used to facilitate the combination.

Arsenite of lime with soda.

White arsenic	pound..	1
Sal soda (crystal)	pounds..	4
Water	gallon..	1

The ingredients are boiled in the required amount of water until dissolved, which will take place in a comparatively few minutes, after which the water lost by evaporation is replaced. To every 40 or 50 gallons of water a pint of this stock solution and from 2 to 4 pounds of fresh slaked lime are added. The chemical compound derived from the combination of the sal soda and the white arsenic is arsenite of soda. In the presence of lime this breaks down and arsenite of lime is formed. It requires 4.4 pounds of crystal sal soda or 1.6 pounds of dry sal soda to combine with 1 pound of arsenic and 2 pounds of freshly slaked lime to combine with 1 pound of arsenic to form arsenite of lime. It is always desirable to have an excess of lime present, in order to prevent all danger of burning; furthermore, this excess is a convenience to the fruit growers, because they can see by the distribution and amount of lime on the foliage how well the spraying has been done. This formula, which is the Kedzie formula, with a very few minor changes, has been used in many different sections of the country with unvarying success. In all of the practical tests under the advice of the writer this solution is used, and is found to be not only as efficient as other solutions, but far cheaper.

Arsenate of lead.

Arsenate of soda	ounces..	10
Acetate of lead	do....	24
Water	gallons..	150 to 200

The arsenate of soda and acetate of lead should be dissolved separately and then poured into a tank containing the required amount of water. These chemicals unite readily, forming a white flocculent precipitate of lead arsenate, which is easily kept in suspension, and can be used in excessive strengths on delicate plants without the addition of lime. When sprayed upon the foliage it forms a filmy, adhering coat, which is but little affected by ordinary rains. There are several good preparations of lead arsenate upon the market. Some of these are prepared in a wet state, others in a dry or powdered form. The moist preparations are much preferable, because the dry powder does not give such a good coat of poison upon the foliage. This poison has given excellent results in use against the codling moth, but on account of its expense it is comparatively little used.

If it is desired to use Bordeaux mixture with any of these solutions the arsenicals are added to the Bordeaux mixture in the same proportions as they would be to a similar quantity of water. At all times the greatest care should be taken to prevent accidental poisoning with these compounds.[a] The fact should be firmly impressed upon all those who have anything to do with these solutions that they are of the most poisonous nature. All packages, boxes, or bottles containing the materials should be plainly labeled and kept in secure places which can be locked. The utensils in which the mixtures are prepared should be thoroughly cleansed or kept in some secure place, so that no mistake can occur in using them for other purposes.

COST OF SPRAYING.

The cost of spraying is so small when compared with the benefits to be obtained that we can say it is the very best investment the grower can make. As with other farming operations, the first year will be more expensive than succeeding years, as by experience the fruit grower will be able to reduce expense considerably without impairing efficiency. It is a very difficult task to estimate the cost of spraying, for many factors enter into the problem. The initial cost of the outfit varies from $15 to $75 for hand-power outfits and from $260 to $275 for gasoline outfits. These outfits can be used for many years, and the parts of the gasoline outfit can be used for other purposes. The cost for spraying material amounts to little.

The cost of the different spraying materials will vary with the different sections of the country, according to the freight rates and the quantities purchased by fruit growers. Where a large amount of

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[a] Although no accidents are known to have occurred from the use of arsenicals in spraying, it is well to know what to do in case of accidental poisoning. If evil effects are noted in the case of persons who constantly handle these poisons, a physician should be consulted. If by any mistake or carelessness a small quantity is swallowed, an antidote should be employed without delay. The following extract in regard to antidotes for arsenic poisoning is taken from Poisons: Their Effect and Detection, by A. W. Blyth:

"In any case where there is opportunity for immediate treatment, ferric hydrate should be administered as an antidote. This converts the soluble arsenic acid into the insoluble ferric arsenate, the ferric oxid being reduced to ferrous oxid. It is necessary to use ferric hydrate recently prepared, for if dried it changes into an oxyhydrate, or even if kept under water the same change occurs, so that after four months the power of the moist mass is reduced to one-half and after five months to one-fourth. When once the poison has been removed from the stomach by absorption into the tissues the administration of the hydrate is absolutely useless.

"Ferric hydrate is prepared by adding strong ammonia to the solution or tincture of ferric chlorid found in every chemist's shop, care being taken to add no excess of caustic ammonia."

Lime water may also be used as an antidote, but it is not so effective as ferric hydrate. It is understood that after the antidote some emetic, such as mustard or warm water, should be administered immediately. Persons who use great quantities of arsenites in spraying, and who are some distance from drug stores, are advised to keep a small bottle of each of the chemicals named to use in making the ferric hydrate. In preparing ferric hydrate continue to add the ammonia until, after being well shaken, a faint odor of ammonia can be observed.

arsenites is used it is advised that they be purchased in 100-pound lots, using 600 gallons of spraying solution as a basis. Taking the prices of these different compounds as they are in the Far West, the following estimates are made:

Paris green:	
Paris green, 4 pounds, at 25 cents	$1.00
Lime, 8 pounds	.04
Total	1.04
Scheele's green:	
Scheele's green, 4 pounds, at 12½ cents	.50
Lime, 8 pounds	.04
Total	.54
Lime arsenite:	
White arsenic, 1½ pounds, at 10 cents	.15
Lime, 3 pounds	.015
Additional lime, 12 pounds	.06
Total	.225
Lime arsenite with soda:	
White arsenic, 1½ pounds, at 10 cents	.15
Salsoda, 6 pounds, at 1½ cents	.09
Additional lime, 6 pounds	.03
Total	.27
Lead arsenate:	
Arsenate of soda, 2½ pounds, at 10 cents	.25
Acetate of lead, 6 pounds, at 12 cents	.72
Total	.97
Prepared lead arsenate, 36 pounds, at 20 cents	7.20

From the foregoing quotations, any fruit grower can estimate the expense of spraying by changing the prices to those prevailing in his vicinity. The prices of these chemicals, excepting the lime and sal soda, are from about 2 to 5 cents per pound more in the West than in the East. The labor of preparing, which is but little, is another factor which must be included. In the preparation of arsenicals for a home orchard or a small commercial orchard it may be advisable for the fruit grower to purchase the more easily prepared compounds, such as Paris green or prepared lead arsenate, as this does away with much trouble and loss of time in preparing the solution.

Labor is the principal element of cost in actual spraying operations. The cost of one spraying for a thousand 8-year-old trees in the far West, using 2½ gallons of lime arsenite and soda compound per tree, is estimated as follows:

Hand-power outfit:	
Man and team 4 days, at $3.50	$14.00
Two men 4 days, at $1.50 each	12.00
Materials	1.12
Total	27.12
Gasoline-power outfit:	
Man and team 1½ days, at $3.50	5.25
One man 1½ days, at $1.50	2.25
Materials	1.12
Gasoline, 1½ gallons	.55
Total	9.17

The above estimates are taken from actual conditions in the field, and the prices of material and labor are based upon current rates in the far West, where they are considerably less than in the East. It is assumed that the men and teams were employed at the local rates; but as men and teams are already employed upon fruit farms, the actual expense of these spraying operations is much smaller. According to these estimates one spraying would cost 2.7 cents per tree if a hand-power outfit is used, or 0.9 cents per tree if a gasoline-power outfit is used. The additional cost to the fruit grower would be much less than this, and in some cases would probably not amount to more than 1 cent per tree with the hand-power outfit, or one-half cent per tree with the gasoline outfit.

TIME AND FREQUENCY OF APPLICATION OF SPRAY.

The time of application of the spray is one of the most important considerations in the work. It has been found that in many sections of the country fruit growers have sprayed without any definite knowledge as to when the spray would be effective, and many times it was not at all so, the effectiveness that it had depending more upon chance than anything else. Other growers follow the empirical rule of spraying once every two weeks after the blossoms have fallen. If this rule is followed no doubt many of the sprayings during the season have little or no effect upon the codling moth. It can be readily seen that to be effective the poison must be placed upon the trees so that when the larvæ are hatching they will get some of the poison; but if they are already inside the apples or in their cocoons they suffer very little from the spraying. Hence we find that where there are but two generations of the insect there are only two periods in the season when a large proportion can be affected by the poison, and these are the proper times for spraying. The work done at these two periods may be termed the early and the late sprayings, the early spraying being directed against the first generation of the codling moth.

Two sprayings at the early period are advised, one a few days after the blossoms have fallen and before the calyx closes, and the other about two weeks later, when the majority of the larvæ are entering the fruit. There has been much discussion recently in regard to dispensing with the spraying immediately after the blossoms have fallen. It has been found that the larvæ enter the fruit from one to two months after the blossoms have fallen. In cases of bad infestation, where preventive measures have been neglected, or there is an abundance of the insect, it might be well to make three sprayings while the second generation is entering the fruit. This period varies with the locality and with the seasons in the same locality; but there are a few methods by which the time can be approximated with sufficient accuracy, and in view of the fact that the time is variable the writer does not wish to recommend that the spraying be dispensed with until each locality is studied. Spraying may be begun immediately after the first new entrance holes of the second generation are found, or about twenty days after the date the maximum of the first-generation larvæ are found under the bands ready to spin their cocoons. The larvæ of the second generation in southern Idaho usually begin to enter the fruit the last week in July, but the majority enter in August, and but few in September. The number of sprayings to be made against this generation depends entirely upon the success achieved against the first generation. It has been found quite definitely that the injury due to the second generation is much greater than that from the first generation; and if the injury due to the first generation is from 2 to 5 per cent the writer advises a third spraying for the second generation; but if the injury has been only 1 per cent or less, two sprayings will be found sufficient. The quantity of lime used in these late sprayings should be reduced to a minimum, as lime on the fruit depreciates its market value.

Light showers wash but little of the spray from the tree; but if there is a heavy shower or continued rain, a large amount will be removed, and it will be necessary to repeat the sprayings as soon as possible. Lead arsenate is less affected by rain than the other spraying compounds.

HOW THE POISON KILLS THE INSECTS.

Though Paris green has been used for spraying purposes for many years with success against the codling moth, it is only recently that any serious effort has been made to ascertain how the poison is obtained by the larvæ. Slingerland was the first to answer this question with any degree of accuracy. According to him the spray lodges in the saucer-like calyx when the young fruit is erect after the blossoms have fallen, and upon the segments or leaves of the calyx closing the poison is held there for some time. As about 80 per cent of the larvæ of the first generation enter the fruit through the calyx, it is easily seen how the majority of them would obtain some poison.

Calyces were analyzed and the poison found in them, showing that the closing of the lobes incloses some poison at least two weeks after the spraying has been done. The writer is unable to find any published record of any larvæ having been found in a calyx, which were killed or supposed to have been killed by the poison. The evidence which goes to show that they are killed is all indirect. In Idaho in 1902 the writer gave special attention to this most difficult point. By examining the apples immediately after the blossom had fallen it was found that the calyx proper consisted of two parts; first, the calyx tube, which we may say is on the interior of the apple, and then the lobes or bases of the lobes which support the stamens. The stamens stand close together and form a sort of roof over the calyx tube. The writer has many times cut open this calyx tube after spraying has been done, and was unable at any time to distinguish any particles of spray inside the tube. The writer is also unable to give any definite figures as to what percentage of the larvæ enter the apple by way of the calyx tube, but it is possible that it is large. The difference in percentages of larvæ which have entered the calyx on sprayed or unsprayed trees should indicate the efficiency of the spray. Table III gives 82 per cent as entering the calyx on sprayed trees and 80 per cent on unsprayed trees. There was lack of data in regard to the sprayed trees, which was not discovered until it was too late to obtain a new series. Cordley finds that the larvæ do not enter the fruit until two months after the petals have fallen, and on that account does not recommend the spraying immediately after the blossoms have fallen.

How the larvæ of the second generation are killed is a question still in a somewhat chaotic state. It is generally believed that the larvæ get the poison when they enter the fruit, but the observations of many investigators, including the writer, show that when the larvæ are entering they eat little or none of the fruit. In both sprayed and unsprayed orchards it is quite common to find places where they have entered the fruit and have died shortly after entering. Countings on 426 new entrance holes in sprayed trees showed that there was an average of 40 per cent of the holes in which the larvæ had died, and in two counts this percentage went as high as 70. Other countings on unsprayed trees gave, out of 606 new entrances, 11 per cent in which the larvæ had died. As there is no way of knowing accurately how many of these holes were caused by larvæ which entered the fruits where two apples touched, these data can not be relied upon, but the writer believes that during the period in which the entrance holes were made at least 10 or 15 per cent of the larvæ succumbed to the spray. Twice larvæ were found dead before they had entered the fruit. Many times early in the season holes were found, the making of which would employ the larvæ for several days. In these cases it is questionable whether or not the spray killed the insects.

In regard to the entrance of the second generation, the larvæ may get some of the poison when their jaws are slipping on the fruit in the attempt to make an entrance, but at best the percentage probably killed in entering the fruit can in no way account for the general efficiency of spraying. Considering the egg-laying habits and the leaf-feeding habits of the larvæ of both generations, the writer is strongly of the opinion that by far the larger number of the larvæ killed by spray are killed through eating or nibbling the poisoned leaves before they find fruits. It is to be hoped that future years will develop more definite data on this subject.

THE BANDING SYSTEM.

As before indicated, upon leaving the fruit the larva seeks some place in the crevices or loose bark in which to spin its cocoon. This fact was known as early as 1746, but it was not until 1840 that Burrelle, of Massachusetts, discovered that by winding something around the tree or placing cloth in a crotch many larvæ would be induced to collect there and could then be destroyed. He recommended destroying them in a hot oven. The banding system was further studied and elaborated by Dr. Trimble, who recommended hay ropes for bands. Very soon this became the most successful method used, and up to about 1880, by its use many fruit growers were able to save considerably more of their fruit than before. Many other observers have made studies of these bands and proved what was best in the way of material and the manner and time of application, until now it is one of the very best adjunct methods in the control of the codling moth. Generally speaking, the system of banding is simply furnishing the larva a good place in which to spin its cocoon and killing it after it has done so. (See Pl. X.)

The materials used for these bands may be designated as temporary and permanent. The temporary bands are composed of hay, paper, or any other cheap material, and, after the larvæ have entered the bands, are burned with the contained larvæ. Permanent bands are usually of cloth; these, after the larvæ are killed, are replaced on the tree. The materials for these bands are various, and it has been found that the most efficient is some dark, heavy material. Bands of thin muslin are quite inefficient. Professor Aldrich recommends brown canton flannel. In orchard practice it is found that fruit growers use almost any material, such as old clothes, burlap, and canvas.

One of the most essential features of the banding system is to render all other places on the tree unsuitable for the spinning of the cocoon, thus leaving the band the only alternative. Cracks in the tree should be filled, the rough bark scraped away, and all other obstacles removed.

The band should consist of a piece of cloth long enough to go around the tree more than once, and from 10 to 14 inches in width. This piece of cloth is folded once lengthwise and placed around the tree. There are many devices for holding the bands in place upon the tree. The one which gives the most satisfaction, and allows the band to be removed and replaced most readily, consists of driving a small nail through the ends of the band after wrapping it around the tree, and then nipping off the head of the nail in such a manner as to leave a sharp point. Subsequent removal of the band is accomplished by simply

FIG. 18.—Large apple tree properly banded for the codling moth (original).

FIG. 19.—Apple tree banded, showing bands both above and below a hole in the trunk (original).

pulling the ends off the nail, and replacement by pushing them down again over it. Ordinarily one band to the tree is sufficient in general orchard practice, but in cases where the trees are large and have a number of large branches, it is advisable to put one band around the trunk and one around each of the larger limbs. (Fig. 18.) Where there are holes in the trees which can not be rendered unsuitable for the spinning of the cocoons, it is the best to put bands both above and below them. (Fig. 19.)

Many writers have experimented upon the effect of several bands upon the tree. LeBaron gives the following table:

Table VIII.—*Number of larvæ caught under bands.*

	Date of examination.				
	July 28.	Aug. 11.	Aug. 25.	Sept. 9.	Sept. 23.
Bands on limbs	43	31	7	9	4
Middle bands	83	13	15	39	22
Lowest bands	94	21	24	33	28

On a single tree, from July 4 to July 23, the same writer found 110 larvæ under the top band and 150 under the lower band.

The author states that the windfalls in every case were left as they fell. In the season of the year when a large number of the wormy apples were on the ground the lower band caught most of the larvæ, while during July, when the windfalls caused by the first generation had hardly begun to fall, the larger number of larvæ were caught by the upper band.

Professor Aldrich experimented upon one large tree and five bands. The table made from these experiments is here given.

Table IX.—*Professor Aldrich's record of bands on one tree.*

	July—				August—				September—				October—			Total.
	7.	15.	21.	30.	6.	12.	18.	26.	4.	10.	17.	25.	1.	8.	15.	
Top	2	27	32	11	20	7	8	4	4	6	....	2	0	20	13	156
Second	0	4	9	12	1	6	13	3	1	3	....	7	8	9	4	80
Third	1	4	5	12	14	6	0	6	2	3	....	3	13	11	6	86
Fourth	1	4	11	11	11	3	4	2	1	2	....	4	7	8	6	75
Bottom	0	3	7	18	17	1	7	8	4	3	....	8	9	7	3	97
Total	4	42	64	64	63	23	32	23	12	17	....	24	37	55	34	494

Out of a total of 494 larvæ about 30 per cent were caught on the upper band, and the lower band caught more than any of the intermediate ones. The experiment also shows that in seeking a place for their cocoons the larvæ will cross several bands, and as there is no way by which those going up the tree and those going down can be separated, no exact percentages of such can be given.

Wickson found by carefully conducted experiments that while 2,704 apples and pears were counted from which larvæ had escaped, there were only 1,188 under the bands, or 44 per cent. The remaining 56 per cent either found other places in which to spin their cocoons or were destroyed by their enemies. The percentage of larvæ caught upon a tree will depend entirely on the condition of the tree. If the tree is free from cracks, holes, and rough bark, more larvæ will be caught; while if there are other places in which they can spin, fewer of them will go under the bands.

It has been fully demonstrated that in badly infested orchards of the West only a comparatively small percentage of the fruit can be saved by bands alone.

After the larvæ have collected under the bands they must be killed or the bands will become a positive aid to the insect. The usual method of examining the bands is as follows: One end is removed from the nail and rolled back upon itself around the tree. As the cocoons, larvæ, and pupæ are exposed they are cut in two with a sharp knife or crushed. Many methods have been devised by which these bands can be collected in wagons and brought to a central place, where they are put in hot water, run through wringers, or some other device used to kill the larvæ; but in view of the fact that many of the worms will crawl out in transit, and comparatively few of them remain attached to the bands, these methods must give way to the one described. Another important point is the length of time which should intervene between the examination of bands and the killing of the larvæ. This time depends entirely upon the length of time which it takes the larva to emerge as a moth after having left the fruit. In the warmer sections of the West 6 or 7 days has been recommended. By extensive experiments carried on by Professor Gillette and the writer it was found that practically none of the moths issue until after 11 days from the time they entered the bands. The data upon which the recommendation of 6 or 7 days was based have in some cases been found to be quite inaccurate. When the trees were examined not all of the larvæ were killed, and the second week afterwards some of them were found to have emerged, and from this the conclusion was reached that some of them went through the cocoon stage in 6 or 7 days. The experiments by the writer and Professor Gillette have been found in practice to allow a small number of moths to escape. A person examining bands frequently can easily tell whether the time is too short or too long. If the time is too long, many empty pupa cases will be found projecting from the band, whereas if the time is too short most of the insects will be found in the larval stage, not having had time to transform to pupæ.

EXPENSE OF BANDING.

When compared with the cost of spraying, banding is comparatively expensive. One man can examine the bands and kill the larvæ on about 300 trees in one day. Counting his wages at $1.50 per day, we find that it costs about $5 a thousand trees for one examination, which is about half the cost of one spraying. The bands should be placed upon the trees in the spring at about the time the earliest larvæ of the first generation begin to leave the fruit. This time is usually about two weeks after the first wormy fruits have been noted, and in southern Idaho is about June 15. It is always well to apply the bands a week or so earlier than there is any necessity for. The bands should be examined every ten days and the larvæ which have collected in them killed. This makes about ten or eleven examinations of the bands in the course of the season. Examination after the first week in September is unnecessary in southern Idaho and practically all of the Pacific northwest, as very few moths emerge after this time. After the fruit has been picked and carried off, the bands should be removed, all the larvæ in them or on the trees killed, and the bands stored, because if they are left in the orchard they will soon rot.

WHEN BANDS MAY BE USED.

Bands may be used to great advantage in an orchard bearing its first crop, which is but little infested. Many growers whose orchards are more or less isolated and but little infested use the banding system as a means of control. One of these is Mr. I. B. Perrine, of Blue Lake, Idaho, who has had great success in keeping the injury in the worst infested section of his orchard down to less than 3 per cent.

The most important use of the bands is as an adjunct to spraying in a badly infested orchard when it is desired to bring the codling moth under control in that orchard, or in general practice when the trees are large and the spraying can not be well done on account of either the inefficiency of the spraying machine or the height of the trees. However, the writer, by many extensive experiments, has clearly demonstrated that when four or five sprayings are made with the gasoline power outfit, and the spraying solution is thoroughly applied at the right time, banding is unnecessary. In orchards where spraying is the only remedial measure used it is advisable to keep bands on four or five normal trees, killing the larvæ at stated intervals and recording the results, so that the band record may act as an indicator for the conditions in the orchard.

PRACTICAL TESTS.

The season's work in 1900 may be summed up in saying that the work accomplished simply outlined the problem of the codling moth in the Pacific northwest. In 1901 the apple crop was so unusually small that all practical tests which had been begun were abandoned, and the time devoted to a study of the life history of the insect and planning a campaign for the following year. It was decided to give the recommendations of previous years a thorough practical test under actual field conditions from the fruit grower's standpoint. Some difficulty was experienced in obtaining orchards in which to work. Keeping in view the idea that the codling moth is the greatest injurious factor in the commercial orchard, a large amount of work was done in such orchards, the principal part in the orchard of the Wilson Fruit Company, near Boise, Idaho, through the kindness of Hon. Edgar Wilson, and in that of Mr. Fremont Wood. Mr. McPherson's orchard and that of Mr. David Geckler were visited frequently and observations made. There were many orchards in various localities in which no measures were used against the codling moth, and these were used as checks upon the sprayed orchards. In Idaho the injury by the codling moth in 1902 was quite variable, as there had been but a scattering fruit crop the year before, and consequently a lack of insects in some localities.

The orchard of the Wilson Fruit Company, which is a type of the very best commercial orchards in Idaho, was planted in 1894 by Hon. Edgar Wilson, and was sold by him to the company which is the present owner in the early spring of 1902. Mr. Wilson acted as manager for the orchard company for the season, aided by Mr. W. F. Cash. This orchard consists of 650 Ben Davis trees, 500 Jonathan, 750 Rome Beauty, 141 Northern Spy, and 800 trees which were planted as Wolf River, but were subsequently budded to Jonathan, and have not yet come to bearing. There are three short rows of Pewaukee, and a few trees of other varieties scattered throughout the orchard.

The house in which the apples were packed and the culls stored in the fall of 1901 is about 200 feet from the orchard and has always been a source of infection for it. (Pl. IV, figs. 2 and 3.) Early in the season of 1902 Mr. Wilson purchased a gasoline-power spray outfit and prepared to give the orchard a thorough spraying. The improvements made by Mr. Wilson and Mr. Cash have rendered this machine one of the most efficient for this purpose. A single spraying was accomplished in about four days, using lime arsenite with soda exclusively as a spraying solution. About 2,000 very heavily loaded trees were in bearing. The conditions of the previous season were such that there was an abundant supply of insects present in 1902, except in the Rome Beauty section. The writer estimated in 1901 that from 40 to 60 per cent of the fruit in the Jonathan and Ben Davis sections was infested, no late spraying having been made; and the small amount of fruit in the Rome Beauty section was all infested.

No bands were used, except upon the trees left unsprayed and a very few near the apple house. The blossoms of the Jonathan and Ben Davis were fully open about May 10, and had dropped about May 20. The Rome Beauty blooms through a longer period of time, and some blossoms were observed as late as June 1. Spraying should have begun about May 19, but on account of continued rains it was delayed until the 23d, at which time the orchard was given a thorough spraying. After two weeks the orchard was again sprayed, at about the time the first larvæ were beginning to enter the fruit. By the 1st of July about all of the larvæ of the first generation had entered the fruit. Countings on the Ben Davis and the Jonathan section gave an average of a little less than 1 per cent infested, while the Pewaukee trees, which were unsprayed, had from 20 to 26 per cent infested. The Jonathan tree nearest the apple house had about 5 per cent wormy, but this percentage decreased rapidly in the surrounding trees. Other orchards in the same condition showed from 10 to 50 per cent wormy; while orchards in which no remedial measures had been applied, and in which no insects were left over from the year before, showed a very small percentage wormy. In the last week of July, at about the time the second generation was beginning to enter the fruit, a third spraying was made; and the fourth spraying was made about August 8, at which time a demonstration was made to visiting fruit growers. About ten days after the spraying a dashing rain washed off a considerable amount of the spray. Mr. Wilson and Mr. Cash did not think it advisable to make another spray, in view of the fact that the results already secured were so satisfactory that they thought it unnecessary. There is no doubt in the mind of the writer that if this spraying had been made the results would have been better.

Harvesting began about the second week in October, at which time the final results were obtained. Many trees were selected early in the season and the wormy fruit upon them counted; but as the season progressed the number was reduced on account of the lack of time to make the proper countings. The following table is compiled from the results upon six average-sized Ben Davis trees which were situated about the center of the Ben Davis section. At all times the greatest care was exercised in making these countings as accurate as possible, every one of the apples being counted and no estimates made.

TABLE X.—*Infested and non-infested apples on six sprayed trees.*

Number of trees.	Date.	Apples on tree.			Fallen apples.				Total apples.	Total apples infested.	Total per cent infested.
		Infested.	Free.	Total.	Infested.	Free.	Total.	Per cent infested.			
1	July 16	15			10	330	340	2			
	Aug. 22	2			29	83	112	25			
	Sept. 4	12									
	Nov. —	153									
	Total	182	1,364	1,517	39	413	452		1,998	221	11
2	July 16	3			21	410	431	4.8			
	Aug. 22	6			45	123	168	26			
	Sept. 4	19									
	Nov. —	143									
	Total	171	1,107	1,150	66	533	599		1,777	237	13
3	July 16	4			26	37	63	41			
	Aug. 22	10			10	16	26	38			
	Sept. 4	11			1	7	8	12			
	Nov. —	167									
	Total	192	977	1,144	37	60	97		1,241	229	11
4	July 16	12									
	Aug. 22	0			32	133	165	19			
	Sept. 4	4			4	10	14	28			
	Nov. —	129									
	Total	145	1,430	1,559	36	143	179		1,433	181	10
5	July 16	4			22	65	87	25			
	Aug. 22				17	46	63	26			
	Sept. 4	12			0	23	23	0			
	Nov. —	152			30	63	93				
	Total	168	1,228	1,396	69	197	266		1,662	237	13
6	Aug. 13	19			19	82	101				
	Sept. 4	7			0	16	16				
	Nov. —	174			50	141	191				
	Total	200	1,210	1,384	69		308		1,892	269	14

The large amount of free fallen apples on trees No. 1 and No. 2 are due to the apples picked off in the process of thinning. The average total per cent infested throughout the season for these trees was 13.

The greatest difficulty was met with in obtaining any reliable estimate upon the general results from the orchard, for the reason that the larger percentage of the seconds and culls were graded as such because they were small or uncolored. The Ben Davis section produced 1,944 boxes of strictly first-class fruit, and the writer estimates that this was only about one-third of the total produced. In one section of the orchard there were trees in which the loss was fully 25 per cent at harvesting time, but there were many others in which the loss was not over 5 per cent. The writer estimates that at picking time about 10 per cent of the fruit in this section of the orchard was infested. In the Jonathan section 2,030 boxes of first-class fruit were packed, and the culls were estimated at 146 boxes. By numerous counts it was found that only about half of these were infested, which gives a total of 73 boxes of infested fruit. As a general result, about 3 per cent of the apples were found infested, and the total percentage for this section of the orchard was probably about 5. It was found that the tree nearest to the packing house was about 50 per cent wormy, but the percentage diminished rapidly toward the center of the block. A few trees which could not be well sprayed on account of their situation with regard to irrigating ditches were more wormy than others. In the Rome Beauty section, in which there was a small crop the year previous, a total of 3,017 boxes of first-class fruit was packed, and it was estimated that one-fourth, or 109 boxes, of the culls and seconds were infested, or about 3 per cent of the whole crop. The Pewaukee apples were practically 100 per cent infested at the end of the season. The apples were counted on an unsprayed Domine tree September 4, and 81 per cent were found infested. From experiences in other orchards with this insect, the writer believes that, had it not been for spraying, the fruit in this orchard would have averaged from 80 to 90 per cent infested. (See Pls. XIII, XIV, XV.)

In Mr. Cash's orchard, which is separated from the Wilson orchard only by a road, it was found that the Jonathans were 25 per cent infested, only two sprayings having been made.

The orchard of Mr. Fremont Wood, which is a type of the best of the smaller commercial orchards, was kept under observation throughout the season. This orchard consists of about 1,000 trees, the larger per cent of which are Jonathan. These trees were set out about 1895. In 1901 the crop was small and was almost totally destroyed by the codling moth. In 1902 a hand-power spraying outfit was used (Pl. XII, fig. 3), which was supplemented by banding. The sprayings were made about the same time as in the Wilson orchard, except that the last spraying was after the rain, about the middle of August, and it was probably more efficient on that account. After the first generation of the larvæ had entered the fruit, it was found that there were not over 3 to 5 wormy apples per tree. Harvesting was begun in October, and at that time it was found that in the Jonathan section, which consisted of about 900 trees, there were 4,700 boxes of first-class fruit packed. Of culls and windfalls there were about 900 boxes, of which, from numerous counts, it was estimated that about one-half, or 9 per cent of the entire crop, were infested.

Mr. McPherson's and Mr. Geckler's orchards are types of old commercial orchards in which the trees are large and the infestation bad. It was only with difficulty that remedial measures could be applied efficiently, as preventive measures had been neglected. In both instances, on account of the height of the trees and their closeness, the sprays could not be well applied. Mr. Geckler estimated his loss as high as 50 per cent, while Mr. McPherson lost as high as 30 per cent on the same varieties. In both of these orchards there is a constant supply of insects from other orchards, and their control requires radical application of preventive and remedial measures.

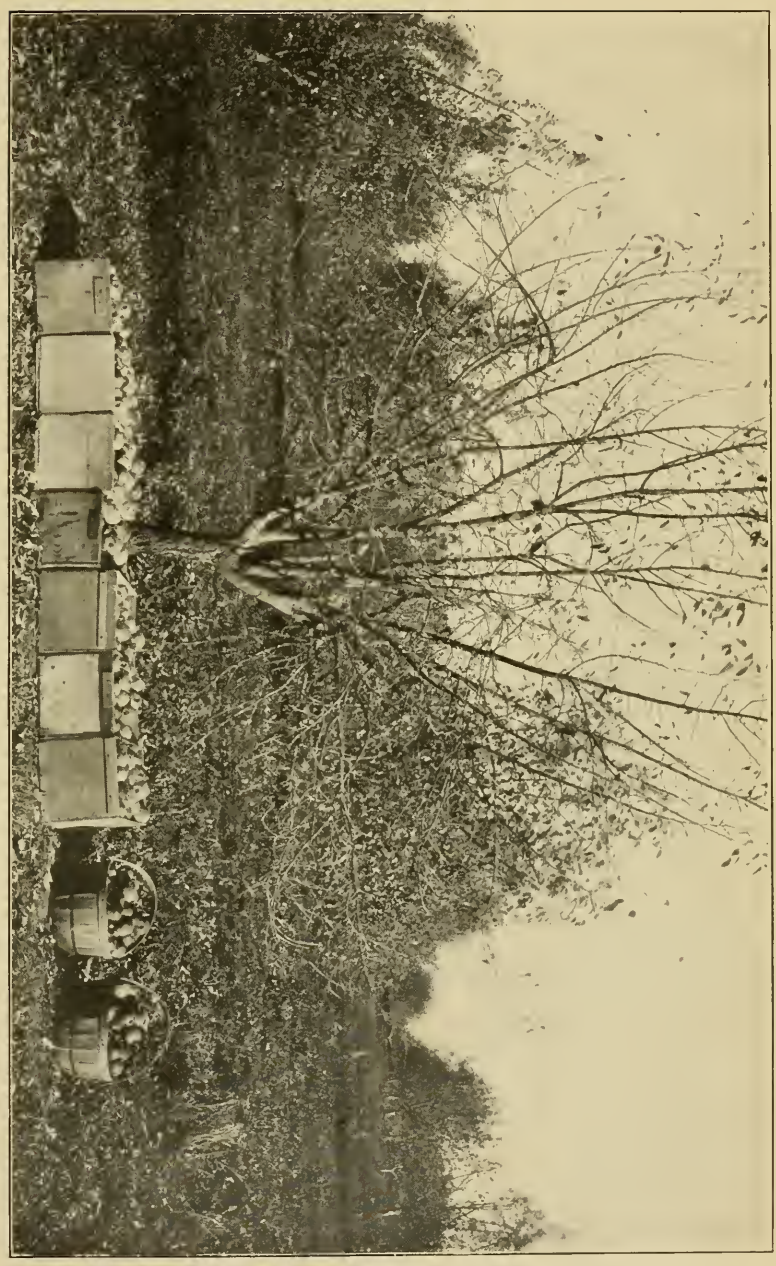
Mr. J. A. Fenton estimates that his crop was only about 15 per cent injured in 1902, he having used bands and spraying. Mr. I. L. Tiner, who has a small orchard in the city of Boise, estimated that he saves about 80 per cent of his fruit each year. Mr. Gus Goeldner, near Boise, estimates that he saves 90 to 95 per cent of his fruit each year. In many sections of the West estimates have been made by fruit growers in which they say they save from 85 to 98 per cent of their fruit. Sometimes these estimates are obtained from countings, but more often they can not be relied upon, the fallen fruit not having been taken into consideration.

The results of practical tests in these orchards show that with four or five thorough sprayings, preferably by a gasoline-power outfit, from about 85 to 95 per cent of the fruit can be saved from the codling moth. By a series of applications of these measures even this margin of loss may be reduced; but the saving of 90 per cent of the fruit under present conditions may be considered a solution of the problem.

RÉSUMÉ AND CONCLUSION.

The codling moth, which is now a cosmopolitan insect, was introduced into the Pacific northwest about 1880. On account of the warm climate two overlapping generations are produced, and if proper measures of control are neglected the insect, under normal conditions, will infest practically the entire apple crop of many localities.

The preventive measures are fully as important in controlling this insect as the remedial measures.



CLEAN AND WORMY APPLES FROM TREE NO. 2, WILSON ORCHARD.

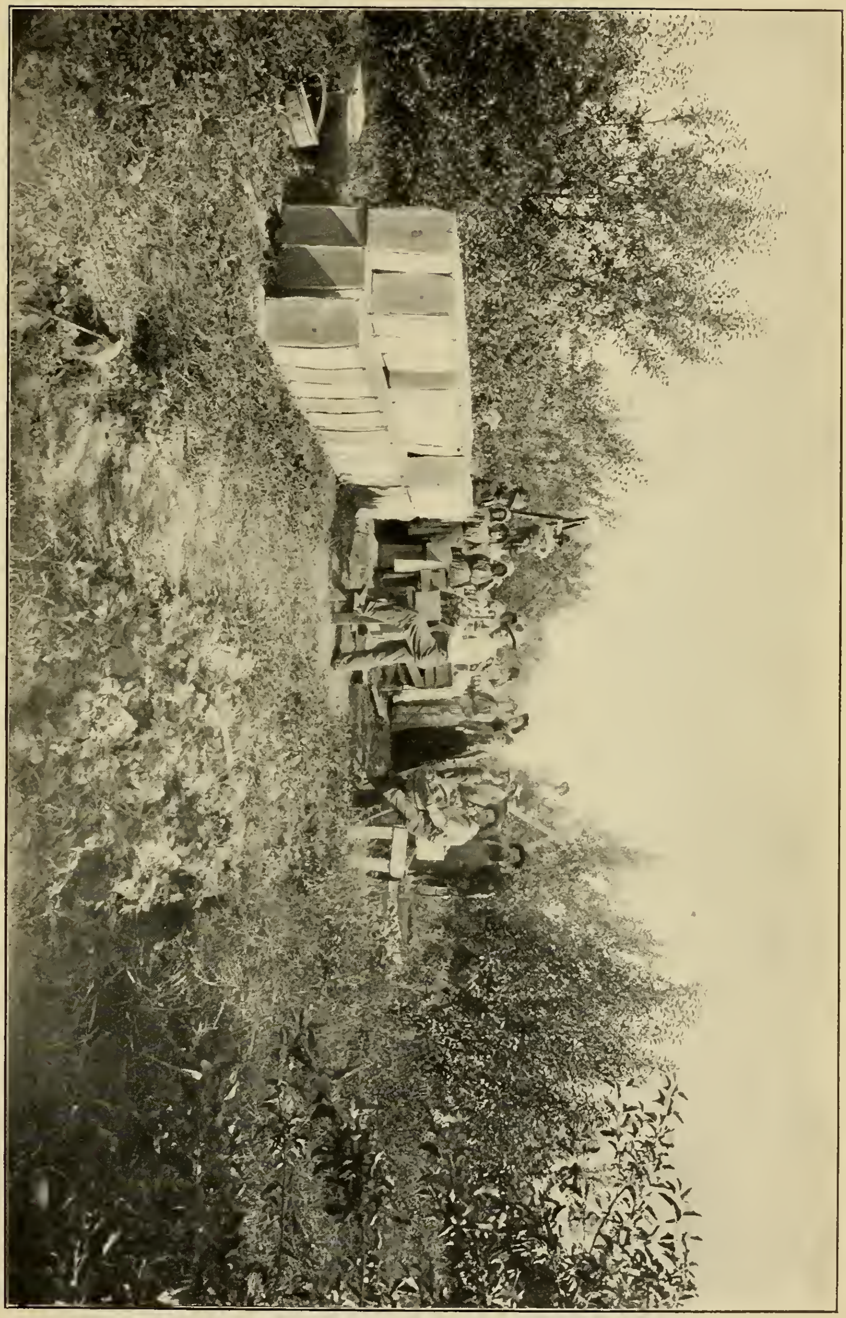
Showing 7 boxes of clean apples and 2 baskets or about 1 box of wormy apples.

CLEAN AND WORMY APPLES FROM TREE NO. 4, WILSON ORCHARD.

Showing 8 boxes of clean apples and one-half of a box of wormy apples from the tree (No. 4), and about $1\frac{1}{2}$ boxes of apples from the ground, of which about one-third were wormy.

CLEAN AND WORMY APPLES FROM TREE NO. 6. WILSON ORCHARD.

Showing 8 boxes of clean apples and 1 box of wormy apples from the tree, and 1 basket of clean apples and 1 basket of wormy apples from the ground.



PREPARING APPLES FOR MARKET, ORCHARD OF HON. FREMONT WOOD, BOISE, IDAHO.

Remedial measures which are of value have been found to be spraying with arsenites and banding. Spraying by the use of a gasoline-power outfit has proved to be the most effective, such spraying, using lime arsenite with soda, having reduced the injury in a certain orchard which had previously been from 40 to 60 per cent to 10 per cent.

By the use of proper preventive measures, spraying and banding, for a number of years, the injury due to the codling moth can be reduced from nearly 100 per cent to 5 or 10 per cent in an orchard in any locality.

BIBLIOGRAPHY OF MOST OF THE MORE IMPORTANT CONTRIBUTIONS TO THE LITERATURE OF THE CODLING MOTH.

The following bibliography down to 1898 is practically a duplicate of that published in Professor Slingerland's Bulletin 142, Cornell Agricultural Experiment Station, pages 63–69:

1635. GOEDAERDT. Metamorphosis Naturalis, Vol. I, p. 98, fig. 46.

Apparently the first published account of the insect. It seems to have escaped notice until 1864, when Werneburg referred to it in his "Beitrage zur Schmetterlingskunde." Lister added nothing of importance in his Latin edition of Goedaerdt published in 1685.

1728. FRISCH. Beschreibung von Allerley Insecten in Teutschland, part 7, pp. 16–17, Pl. X, figs. 1–5.

Grotesque and yet quite accurate descriptions of moth and larvæ; believed it preferred to work in unhealthy or injured fruits. No definite data on life history.

1736. REAUMUR. Mem. pour servir a L'Histoire des Insects, Vol. II, pp. 484, 496–499, pl. 38, figs. 11, 12, and pl. 40, figs. 1–10.

Good account of work of larva in fruit and in making its cocoon. Two broods indicated.

1746. ROESEL. Insecten-Belustigung, Vol. I, part 6, No. 13, pp. 33–37, pl. 13, figs. 1–5.

In accuracy of detail and coloring the hand-painted figures equal, if not excel, any colored pictures of the insect published since. Good account of original observations upon its life history; thought the newly hatched larva sometimes entered the fruit beneath the eggshell, and that the worms sometimes left one apple and went to another fresh one. One brood indicated. All stages, except the egg, well described.

1747. WILKES. The English Moths and Butterflies, Book I, class 1, p. 5, no. 9, pl. 65 (copies of Roesel's figures).

Probably the first English account; brief compilation from Roesel. Gave to the insect its name of "codling moth," from the codling tree, which is also figured.

1758. LINNÉ. Systema Naturæ. Ed. X, p. 538, no. 270. *Tinea pomonella*, "Alis nebulosis postice macula rubra aurea."

Original description of the insect when it received its first scientific name.

1791. BRAHM. Insektenkalender, Vol. II, p. 465.

Brief account with many earlier references. Common and sometimes destructive in orchards; and records its habits in fruit rooms.

1802. DE TIGNY. Historie Nat. des Insectes, Vol. IX, p. 256.

Largely a compilation from Reaumur and Roesel. Says eggs are laid on fruit before petals fall.

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Mostly a compilation from Roesel and Brahm.

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1819. TUFTS. Massachusetts Agricultural Repository and Journal, Vol. V, 364–367.
Apparently the first account of the insect in American literature. Previous American writers had credited the plum curculio with the cause of "wormy apples." Records some original breeding experiments by which he was led to conclude that the cause of most of the wormy apples in Massachusetts was a moth, and not a beetle or curculio.

1825. THATCHER. American Orchardist, second edition, p. 116.
Records finding the worms on the trunks of trees, and therefore advises scraping off the rough bark and washing trunks with Forsyth's composition. Apparently the first notice of the insect in horticultural books, and the first one to make any recommendations for controlling the insect.

1826. KIRBY and SPENCE. Introduction to Entomology, III, p. 123.

1829. TREITSCHKE. Die Schmetterlinge von Europa, Vol. VIII, pp. 161–163.
Many references to earlier literature. Descriptions. Brief compiled account of life history.

1831. CURTIS. Brit. Entom., VIII, pl. 352.

1833. "RUSTICUS." Entomological Magazine, Vol. I, pp. 144–146.
A very good detailed account of the life habits of the insect. Eggs laid in the calyx cup. One brood. Apparently the first important article in the English literature.

1833. BOUCHÉ. Garten-Insekten, pp. 113–114.
Brief compiled descriptions and account of habits. All that can be done to control it is to collect and feed out all wormy fruit as fast as it falls.

1834. STEPHENS. Ill. Brit. Ent. Haust., IV, p. 119.

1837. SCHMIDBERGER. In Kollar's Naturg. der schäd. Insecten. (For English translation see Loudon and Westwood's edition of Kollar, pp. 229–232, date 1840).
Good general account. Two broods indicated. (He published an earlier and more complete account in his Natur. der Obst. schäd. Insecten, to which we have not had access.)

1838. WESTWOOD. Gardiner's Magazine, Vol. XIV, pp. 234–239.
Mostly a good compilation from the accounts by Reaumur and "Rusticus." One brood indicated.

1840. BURRELLE. New England Farmer, Vol. XVIII, no. 48, June 3, p. 398. "On the Curculio."
Records breeding the moth. One brood only. Apparently the first one to suggest the famous "banding" method.

1840. RATZEBURG. Die Forst-Insecten, Vol. II, pp. 234–236, pl. 14. fig. 7.
Very good general account. Believes there is but one brood in North Germany, and doubts Schmidberger's account of two broods in South Germany.

1841. HARRIS. Insects of Massachusetts, pp. 351–355. (In the editions of 1852 and 1862 no change occurs.)
Very good general account. Only one brood indicated.

1843. GAYLORD. Trans. N. Y. State Agr. Soc., p. 158.
Brief account with Westwood's figure. Recommends allowing swine to run in orchard. Insect then common in New England, but very rare in the Middle States.

1844. LÖW. Schädliche Insecten, pp. 239–241.
Largely a compilation from Roesel, with good discussion of remedies.

1845. DOWNING. Fruits and Fruit-trees, p. 66.
Brief account.

1846. MORRIS, Miss. ("Old Lady.") American Agriculturist, Vol. V, February, pp. 65–66.
Good account, with original observations, and illustrated by what is probably the first original figure of the insect to appear in American literature.

1849. COLE. American Fruit Book, p. 89.
Brief account. Reports it numerous in New England and along the seaboard, and becoming more common in the Middle States.

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Brief account of breeding experiments. Two or three broods indicated. Discovered that a cloth in the crotch enticed many worms, and after experiments with wax recommends that trees be sprayed with whitewash to fill blossom end of fruits and thus prevent egg laying at this point.

1855. NÖRDLINGER. Kleinen Feinde der Landwirthschaft, pp. 339–346.
One of the best and most complete accounts which have appeared in the German literature. Very good discussion of remedies. Believes it is single brooded in Germany.

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Fairly good general account. One brood.

1868. WALSH and RILEY. American Entomologist, Vol. I, pp. 3–6.
Evidence in favor of allowing hogs to run in orchards.

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Arguments for two broods in Illinois.

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1869. WALSH and RILEY. American Entomologist, Vol. I, pp. 112–114.
Very good general account, illustrated by Riley's well-known figures. Two broods.

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1873. RILEY. Fifth Missouri Report, pp. 46–52.
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Records the successful use of London purple to destroy the insect; first test of poisons made by entomologists.

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1881. Cooke. Insects injurious to California Fruit and Fruit Trees, pp. 13–19.

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1887. Cook, A. J. London purple against codling moth. Agricult. Sc., I, 9, Sept., 1887, p. 215.

1887. Forbes. Bul. No. 1, Office of State Entomologist of Illinois, 26 pp.
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1887–88. Claypole, E. W. Spraying for the codling moth. 21st Report Hort. Soc. Ohio, pp. 212–214.

1888. Howard. Report U. S. Department of Agriculture for 1887, pp. 88–115.
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Results from one, two, and three sprayings, and general conclusions from eight years' experimenting with poisons.

1888. McMillan. Bul. 2, Nebraska Experiment Station, pp. 68–77.
Very good general discussion of habits and especially of remedies.

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Valuable record of careful experiments with poisons and bands, including tables giving dates of blossoming of many varieties of apples.

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U. S. DEPARTMENT OF AGRICULTURE,

DIVISION OF ENTOMOLOGY—BULLETIN No. 42.

L. O. HOWARD, CHIEF OF DIVISION

DIV. INSECTS.

SOME INSECTS ATTACKING THE STEMS OF GROWING WHEAT, RYE, BARLEY, AND OATS,

WITH

METHODS OF PREVENTION AND SUPPRESSION.

PREPARED UNDER THE DIRECTION OF THE ENTOMOLOGIST,

BY

F. M. WEBSTER, M. S.,

Special Field Agent.

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WASHINGTON:

GOVERNMENT PRINTING OFFICE.

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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., September 25, 1903.

SIR: I have the honor to transmit herewith the manuscript of a paper entitled "Some insects attacking the stems of growing wheat, rye, barley, and oats," prepared under my direction by Prof. Francis M. Webster, temporary field agent of the Division of Entomology, and now stationed at Urbana, Ill. Professor Webster has acted as field agent of this Division, having received temporary appointment since 1884, with headquarters at the experiment stations of Indiana, Ohio, and Illinois, and is ably qualified for the prosecution of the present work through years of study in the States mentioned of the insects which will be treated. As remarked in the introduction, this paper deals with the injuries committed to small grains by different forms of minute flies, eight species in all, which are generally confused by the average farmer with the Hessian fly. The differences between these various species and their method of attack in comparison with that of the Hessian fly are duly pointed out, and many valuable suggestions based upon an intimate knowledge of the habits of these insects are made for the mitigation of their ravages. In most instances losses by these insects could be prevented by the simplest of farming practices, as set forth in their proper place. I recommend the publication of this report as Bulletin No. 42 of this Division. The fifteen text figures are necessary for the purposes of illustration, those illustrating plants having been kindly loaned by the office of Agrostologist.

Respectfully,

L. O. HOWARD,
Entomologist and Chief.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

SOME INSECTS ATTACKING THE STEMS OF GROWING WHEAT, RYE, BARLEY, AND OATS.

INTRODUCTION.

Throughout the United States, where the smaller cereal grains—wheat, rye, barley, and oats—are to any considerable extent cultivated, a multitude of injuries to growing wheat are charged by the average farmer to the Hessian fly; whereas, in many cases these ravages are really the work of insects whose habits differ greatly from those of that insect. Indeed, some of them are not flies at all, and even where the ravages are caused by flies, these are not necessarily the Hessian fly, and the same remedial and preventive measures that are applicable to this notorious wheat pest may not be at all effective against them. In fact, it is with the hope of enabling the farmer, as also the economic student, to distinguish between some of the chief insect enemies of cereal grains, and especially between many of them and the Hessian fly, that this publication has been prepared.

In the following pages the author has restricted himself to the consideration of two groups of grain-affecting insects, the one composed of true flies, and the other not, though both during their developmental stages live and thrive within the stems of wheat, and to some extent within those of the growing grasses as well. Indeed, as a whole, they were doubtless primarily grass feeders, and their grain-attacking habits, being of more recent origin, brought about by the changed conditions of their natural food supply, consequent upon the influences of advancing civilization, may be looked upon as a modification of their original methods of living.

While this variety of food plants, including the wild grasses, as well as the cultivated grains, probably has the effect of more generally diffusing some of these insects, thus rendering serious outbreaks of less frequent occurrence, the other phase of the problem is that though the farmer might exterminate them from his fields, they would still inhabit the grass lands and from there continually send a fresh supply of colonists into his fields to repopulate them. But, again, this has its redeeming features, as it enables the grain grower, in some cases, to meet his enemies in the grasses and there fight them to better advantage to himself than in his cultivated fields. The Hessian fly is an exception, as it has yet to be found attacking the grasses in this country; yet several insects whose injuries in the wheat fields have been charged up to it by the farmer may be destroyed to a greater or less extent by closely pasturing the roadsides and fence corners in summer or burning them over in winter or early spring.

The first group of these grain-attacking insects to which attention will be here given is composed of those that are not flies at all in the true sense of the term, but small ant-like creatures, really related to the ants which they so closely resemble. Their young live within the stems of the smaller cereal grains and grasses, and, though these rarely kill the wheat stems outright, they may either prevent the production of the kernels or cause these last to shrink and shrivel, thereby greatly reducing them both in weight and market value. These insects are called the grain and grass Isosomas, and their young are the wheat straw-worms and the joint-worms. What is still more surprising, they belong to a group of insects the majority of which are not vegetable feeders, but parasitic on other insects, and it was a long time before entomologists were willing to accept the fact that they were the real depredators and not parasites. This doubt as to the real food habits of these insects had not entirely disappeared up to 1884, when the author proved by successive rearings not only the vegetal habits of one of the species, but also the even more interesting fact of dimorphism and an alternation of generations, showing that what appeared to be two species was really two generations of one of them; but one of the generations, being wingless in the adult stage, renders it the more easily controlled by the farmer through a rotation of crop.[a]

The second group of insects here considered is composed of true flies, and these also are both grain and grass feeders in the larval or maggot stage. All true flies have but two wings, and the maggots have no jaws, but the mouth parts consist of two minute hooks whereby they tear or slightly wound the surface of the tender stems and suck the juices flowing therefrom. The Hessian fly is also a true fly, but its form partakes more of that of the mosquito, while these under consideration have very much the form of the common house fly, except that they are smaller, and they are frequently quite differently colored. The maggot of the Hessian fly is larger and more robust than are those of the Oscinids, though shorter and differing in color from those of Meromyza.

Judging from my own experience and observation, these insects are much more injurious to the young grain plants. One brood of maggots of Meromyza work in the full-grown straw it is true, but, as a rule, the injury at that time is seldom very severe, while the larvæ of the Oscinids are rarely found in the full-grown straw, except in the

[a] Reports U. S. Comm. Agr., 1884, pp. 383–387; 1885, pp. 311–315; 1886, pp. 573–574.

extreme north, notably in Minnesota, and in Manitoba and the Northwest Territories in Canada. The Isosomas do not attack the grain plants in the fall, and thus we have a natural division between the two, which is applied in the discussion of these insects in the following pages.

The Oscinids are not destructive in this country alone, as allied species have long been a serious pest in England, France, Germany, and Sweden. The frit-fly (*Oscinis frit* Linn.), is some years especially destructive in Europe. The gout-fly (*Chlorops tæniopus* Meigen) and the wheat bulb-fly (*Hylemyia coarctata* Fallen) are both more or less injurious to small-grain crops in England.

In the preparation of this bulletin the writer has been greatly aided by Dr. Howard and his corps of assistants, both in the Department of Agriculture and also in the United States National Museum, and by Dr. S. A. Forbes in kindly and promptly placing the notes and collections of the Illinois State Laboratory of Natural History at the author's disposal. The writer is also indebted for specimens to Dr. James Fletcher, entomologist and botanist for the Dominion of Canada, and for similar favors received from Prof. F. L. Washburn, State entomologist of Minnesota.

THE GENUS ISOSOMA.

The grass and grain joint-worm flies belonging to this genus are widely distributed in America, some of the most important ranging from the Atlantic to the Pacific coasts and from Canada southward probably as far as the grains, wheat, rye, and barley are grown.

The genus Isosoma is known to inhabit Europe, Africa, Madeira, St. Vincent, Australia, and Tasmania. In Europe it ranges over Russia, Switzerland, Germany, Austria, and Italy. When the insect faunas of Asia and Central and South America come to be better understood, we shall in all probability find that species occur in those countries also.

These insects belong to the Chalcididæ, a family of parasites whose normal food is other insects in one or more stages of their development. For a long time entomologists refused to believe that the species of Isosoma and their allies were exceptions to this supposed rule, and Harris firmly believed that *Isosoma hordei* was a parasite and not the true depredator in barley straw. Dr. Asa Fitch afterwards established the fact of phytophagic habits in *I. hordei* as well as in several other species, but English and European entomologists were not wholly convinced, at least not all of them, up to as late as 1882. When the writer began the study of grain-infesting Isosoma in 1884, comparatively little was known of the habits of some of our most common species, and the establishing of the fact of dimorphism and alternation of generations by him in the case of *Isosoma tritici* Riley, as it was then known, and *I. grande* was without a parallel, in this genus, and so remains in this country. Among the ten or twelve American species that I have reared, none of the others, so far as I have been able to determine, enter the pupal stage in the fall and winter in that condition,[a] and thus the greater wheat straw-worm (*Isosoma grande*) is one stage in advance of the others in spring, and the spring form, *minuta*, is developed at the time when other species are entering the pupal stage. This is also the only species that I have not succeeded in rearing from food plants other than wheat, with the possible exception of *Isosoma websteri*, which might have been reared from young cheat plants, though I hardly think this probable. The fact that I have only found this latter species in spring, and then only females, is indicative of a dimorphism and alternation of generations; but unless it be an undescribed species reared from stems of *Tricuspis sesleroides*, which is very late to mature, being even later than any other species known to me, I do not think such alternation can be connected with any other species that I have studied. On the other hand, and at the other extreme in the matter of food plants, the Elymus Isosoma (*I. elymi* French), has never been with certainty reared from wheat, though abundantly from the stems of cheat growing among wheat and from Elymus growing along the margins of wheat fields.

I also find, much to my surprise, that I have reared Fitch's *Isosoma tritici* aside from its known food plant, wheat, only from *Elymus virginicus*. Even where this latter grass and the closely allied *E. canadensis* have grown side by side, the joint worm (*Isosoma tritici* Fitch) has held strictly to the former. The white-spotted Isosoma (*I. albomaculata* Ashmead), perhaps the most closely allied to *I. grande* of any of the species known to me, and which we should suppose would more than any other incline to dimorphism and alternation of generations, seems, however, to show no such tendency, and, moreover, I have reared it from both cheat and *Elymus virginicus*, the life cycle, so far as I have been able to follow it, being parallel with those of *Isosoma elymi*, *I. tritici*, and *I. hordei*. I do not, of course, wish to obscure the possibility of an alternation of generations among these insects, with a different food plant for each generation. On the opposite page is given in tabulated form the food plants of the species of Isosoma known to attack grains and grasses in North America.

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[a] Should the observations of Dr. Andrew Nichols, given under *Isosoma hordei*, prove correct, this may in future prove erroneous as to *I. grande*, unless the latter also attacks barley.—F. M. W.

	I. grande.	I. hordei.	I. tritici.	I. hirtifrons.	I. websteri.	I. secale.	I. elymi.	I. captivum.	I. maculatum.	I. albomaculatum.	I. bromi.	I. hageni.	I. agrostidis.	I. bromicola.	I. fitchii.	I. californicum.
Wheat	×	....	×	....	×	×?	....	....	....	....	....	....	....	....	×?	....
Rye	....	×?	×	×	....	×	....	×?	....	....	....	....	....	....	×?	....
Barley	×?	×	×?	....	....	×?	....	....	....	....	....	....	....	....	×?	....
Elymus virginicus	....	....	×	....	....	....	×	....	....	×	....	....	....	....	....	....
Elymus canadensis	....	×	....	....	....	....	×	....	....	....	....	....	....	....	....	....
Cheat	....	....	....	×	....	....	×	....	×	×	....	....	....	....	....	....
Bromus ciliatus	....	....	....	....	....	....	....	....	....	....	×	....	....	×	....	....
Eriocoma cuspidata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×?
Agrostis sp. ?	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....
Quack grass	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....

DEALING WITH THE DESTRUCTIVE SPECIES OUTSIDE OF THE GRAIN FIELDS.

In attempting to control the grain-infesting Isosoma, the practical farmer will, in several ways, find himself at a disadvantage. The very deceptive resemblance of these insects to ants, and also to others actually beneficial, will prevent his readily recognizing them in the fields, even if he were to see them at all, and it is only when, by accident, perhaps, that he finds the worms in the stems of his grain, that he will ordinarily be able to detect their presence. As the development of the insect takes place entirely within the straw, rarely, except in the case of two species, showing any external effects, much injury may occur to the kernels of grain without his being able to determine the cause. It is, therefore, advantageous to him to know that he may reduce the chances of injury by careful attention to the uncultivated areas that inevitably surround his cultivated fields. As an illustration of the influence of neglecting uncultivated patches like fence corners and roadsides, and allowing these to become overgrown with the different species of rye grass (Elymus), I give the results of my own rearings of these insects from stems of grasses, taken from two different localities along the Illinois Central Railway. In connection with what is here given, it might be well to call attention to the fact that the grounds within the fences along our more important railways are usually better kept than are similar uncultivated grounds along the highways, to say nothing of the fence corners, borders of open ditches, and similar tracts on the premises of the farmers themselves.

The locality from which I secured the greatest number of barley straw-worm flies (*Isosoma hordei*) is situated about 2 miles north of Champaign, Ill. The contour of the ground is such that mowing over in summer is difficult, and burning over in winter, though practical, probably did not seem necessary to the railway people. As a consequence, a small tract grew up to the Canadian rye grass (*Elymus* *canadensis*, fig. 1), the stems of which literally swarmed with the larvæ of this species. It beyond question would have furnished enough adults to have stocked hundreds of acres of barley had it been within reach. The presence of the old stems clearly indicated that the place had been neglected for years, and grass stems of the previous year were filled with punctures where the adults had made their escape. Without anyone knowing it, there was here kept a perpetual nursery for barley straw-worm flies, and though not at present a barley country, it is true, it is easy to see what the effects would be were the situation otherwise and must be elsewhere where this grain is more largely grown.

The locality from which I secured the least number of these insects, and, in fact, none of the grain-attacking species at all, is located along the same railway, in the edge of the village of Peotone, Ill. Here the topography of the ground along the railway is even worse than that in the Champaign locality, but close proximity to the village rendered more attention to it necessary. I am informed by those living near the place that it is regularly mown off during the latter part of June and again in September. The material used in my breeding experiments was collected August 12 at Champaign and August 21 at Peotone, and, though the Canadian rye grass was much more abundant in the latter locality, and to all outward appearances at the time the material was secured offered the joint-worms a far superior place to develop there, yet with ample material I did not obtain a single individual, though in Dekalb County, about 60 miles west of Chicago, where, to my certain knowledge, no wheat or barley has been sown for years, from grass collected August 20 I reared quite a number of these insects. The Dekalb County material was collected from along the neglected roadsides in the country. I can see no possible explanation of the difference in abundance of the joint-worms in the rye grass secured at Champaign and that secured at Peotone, except the difference in the attention given to mowing off the grass during the summer—the same attention that farmers can without trouble give to the roadsides, fence corners, and ditch borders on and about their own premises. These things are a part of good husbandry, yet among intelligent farmers I have found the two species of rye grass growing not only by the roadsides, but along the very borders of their wheat fields, in some cases the grass and wheat being intermixed along the extreme edges of the fields of grain.

Fig. 1.—Canadian rye grass (*Elymus canadensis*), (after Scribner).

Under much the same conditions I have reared the greatest numbers of joint-worm flies, at present known as *Isosoma tritici* Fitch, from the Virginia rye grass (*Elymus virginicus*, fig. 2). In this case the grass from which I secured these insects in greatest profusion came from the most neglected roadsides. In the vicinity of the city of Urbana, Ill., I secured material from two localities, one quite near the resident quarter, where the city government required the mowing off of weeds and grasses, commencing in June, and the other farther from town, along a neglected bank where the grass was allowed to grow up undisturbed year after year. From grass stems from the former locality I secured almost nothing, while from that coming from the latter locality I obtained enough to show that there was here a constant menace to the wheat fields in the neighborhood. Now, as a matter of fact, there is comparatively little wheat or rye grown in the neighborhood, and until I reared these insects from the wild grasses I could not account for their sudden appearance in the wheat and rye fields, observed and recorded in former years by Professor Forbes and his assistants. What has proven true here has been shown to follow similar conditions elsewhere in both Illinois and Indiana. That is to say, where farmers have allowed these grasses to grow up about their farms year after year under the impression that they were not worth any attention, I have found the insects in abundance, and also find that despite their otherwise good farming, they have probably suffered more or less from the attacks of the two species of destructive Isosoma in their grain, though they may not have observed them or their subtile effects on the kernels of the wheat and rye. I am convinced that there is an element of loss here of which farmers are unaware and the precise effects of which they do not therefore comprehend, yet might if they realized the situation.

FIG. 2.—Virginia rye grass (*Elymus virginicus*) (after Scribner).

THE GREATER WHEAT STRAW-WORM.

(*Isosoma grande* Riley. Fig. 3, form *minuta;* fig. 4, form *grande.*)

PREVIOUS RECORD OF THE INSECT.

The history of this species extends back only to 1880, though it was probably for many years confused in wheat with the joint-worm. It sometimes occurs that insects which the systematist can only consider distinct prove on thorough study to belong to one and the same

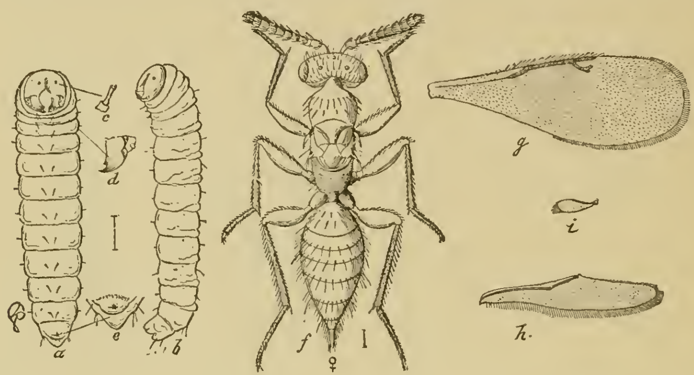

FIG. 3.—Greater wheat straw-worm (*Isosoma grande* Riley), spring generation, form *minutum: a, b,* larva; *f,* female; *g,* fore-wing; *h,* hind-wing; all much enlarged (from Riley).

species, while, on the other hand, it sometimes occurs that what the systematic entomologist considers the same species prove on investigation to be entirely different, and thus the problem of control, if injurious, is either simplified or complicated, as the case may be. However easy it may appear to the farmer, to learn all of the life history of an insect is not unfrequently a matter of no little difficulty. Where we can follow out the life cycle of a species accurately, there is usually found some place or period in its existence when it is more easily controlled or destroyed than at any other time, and it often occurs that at the critical point some simple manipulation of his land or his crop, on the part of the farmer, will accomplish wonders. This species seems to offer illustrations of all of these features.

FIG. 4.—Greater wheat straw-worm (*Isosoma grande* Riley), adult summer form, much enlarged (from Howard).

In June, 1880, Mr. J. K. P. Wallace, of Andersonville, Tenn., sent to Dr. C. V. Riley a number of wheat straws containing larvæ, with the complaint that nearly every stalk or straw was affected by them, and, as a consequence, the straw was inclined to fall before the grain had fully ripened. Mr. J. G. Barlow, of Cadet, Mo., about this time also complained of a similar trouble in his neighborhood, in some cases resulting in nearly a total loss of the crop. In the winter of 1881–82, Dr. Riley was able to rear some 30 adults from these infested straws, and, as he considered the species described by Dr. Fitch only a variety of the barley straw-worm (*Isosoma hordei* Harris), he described the adults obtained from these straws as *Isosoma tritici* Riley, which description was published in the Rural New Yorker March 4, 1882. This was the situation and the condition of our knowledge of the species at the time the writer was appointed a special agent of the Division of Entomology, of which Dr. Riley was then chief, and under his instructions began the study of these and other grain insects in May, 1884.

DISCOVERY OF THE SUMMER FORM.

On May 8, 1884, in a field of wheat near Bloomington, Ill., I found *Isosoma tritici* Riley, as it was at that time known, in considerable numbers, crawling over the young wheat plants, and on the 11th of the same month watched a couple of females deposit their eggs in these growing plants. On May 30, while examining plants from this same wheat field, young Isosoma larvæ were found in the stems, and I also found larvæ in the stems in which I had observed the captured females to oviposit May 11, but these last were much too large for *Isosoma tritici*. During the previous few days I had been getting from fields of both wheat and rye in the same locality a much larger Isosoma, possessing fully developed wings, and on May 29 a pupa, also too large for *I. tritici*, was found in the upper part of a dwarfed wheat plant. In the light of more recent studies we now know that I had three species under observation instead of one. The small individuals found early in the month of April belonged to the spring form of this species, and others were *Isosoma websteri*, while the larger individuals swept from wheat and rye, later in the month of May, were some of them the summer form (*I. grande*), and others belonged to another species, afterwards described as *Isosoma captivum* Howard. My field of observation was at this time transferred from Bloomington, Ill., to Oxford, Ind.

On June 6, in a field of wheat near Oxford, I observed female Isosomas, seemingly like those taken a few days before in the wheat and rye fields near Bloomington, ovipositing in wheat plants, well up toward the top of the stem, probably between the upper joint and the one next below, although, on account of the head of the wheat having not yet put forth, it seemed as though the egg was being placed in the upper joint. A large number of these adult females were secured, and these constituted the types upon which the description of *Isosoma grande* was based.[a]

DISCOVERY OF DIMORPHISM AND ALTERNATION OF GENERATIONS.

At harvest I arranged with the owner of the field near Oxford to allow a small area where I had witnessed the oviposition of the female Isosomas to remain uncut, and I afterwards secured these straws, a part being kept out of doors and the remainder kept within doors during the following winter. Some conception of the extent to which these straws were tenanted by the larvæ of this species may be gained by the fact that of 90 straws from the same field 81 were infested and contained 136 larvæ. These straws were cut close to the ground, and, therefore, the contained larvæ represented the total number. Of 90 straws as cut by the harvester, there were a far less number of larvæ present, only 25 being found in the entire lot, the remainder having been left in the stubble.

By October all of the larvæ had pupated, and my first adult was obtained December 7 from the lot of straws kept indoors. From this time on till June I continued to secure adults issuing from these straws, but everyone of them were *Isosoma tritici* Riley. All of the straws were now split open in order to determine whether or not any individuals still remained, but none were found.

My first adult from the straws kept out of doors appeared March 23, and others continued to appear up to the first week in April, all, as with the straws kept indoors, being *Isosoma tritici* Riley. These straws were now split open and examined, but there was no trace of *Isosoma grande*, which I knew had deposited eggs in these very straws. Despite all this, on June 1, in sweeping the grass along the borders of a wheat field at Lafayette, Ind., only about 20 miles from where I had found them the previous year, I captured *Isosoma grande*, and on the following day found them present in the wheat fields.

During the fall of 1885 I took the precaution to sow a small plat of wheat and so protect it that no insects could reach it. The cover was renewed in spring, and some of the *Isosoma tritici* emerging from straws taken from the field the previous summer were placed in the inclosure where the young protected wheat plants were growing. The adults were placed on this young wheat April 12, and the utmost care taken to prevent any other insects from reaching them,

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[a] The records and material in the files and collections of the State Laboratory of Natural History show that what is probably the larvæ of this species was found in abundance in wheat straw in the fields in southern Illinois, in July, 1884, and adults of the summer form (*grande*) were collected by Mr. Garman, at that time an assistant of Dr. Forbes, in various localities in southern Illinois, during late May and early June, 1884, or just about the time that I began to observe it about Oxford, Ind.

and, besides, the fields were closely watched for *Isosoma grande*. On June 2, fifty-one days after, I found a female of *Isosoma grande* in the inclosure and in the act of ovipositing in the now full-grown wheat plants. Others were observed similarly engaged during the following fortnight, and when the straw was ripened it was cut off and placed in glass jars. I had thus again reared the one supposed species from the other. During the following winter many adults were reared from these straws, but all were of the one form (*I. tritici* Riley), and I had reared the two forms twice from each other, leaving now no further doubt that they were simply two generations of the same insect, besides showing that as the spring generation is without wings and can not fly from one field to another, a simple rotation of crop on the part of farmers would result in keeping the insect so reduced in numbers as to place it out of necessary consideration as a wheat-destroying insect.

In all of my own rearings of both forms of this species I did not secure a single male, and of the large number reared at the Department of Agriculture at Washington, from material furnished by me, but three individuals of this sex were obtained.[a]

RILEY'S NAME, ISOSOMA TRITICI, INVALID.

In a more recent study of these insects,[b] Dr. L. O. Howard found that the species described by Dr. Fitch as *Isosoma tritici* was a valid one. This being the case, Riley's name must no longer be used, and the later one, *Isosoma grande*, thus covers both. Doctor Howard has given the name *minutum* to the wingless spring form, and this name will hereafter be used in this paper.

LIFE HISTORY.

The insect passes the winter in the center of the straw, just above the joint, in the pupal stage. Rarely an adult will emerge in late autumn, but if kept indoors others will appear during December, the most during January, showing that they are ready to appear during the first settled warm weather in spring. In further proof of this, I have found that as the winter advances they require less time indoors in which to develop than if the straws are brought in in December, thus showing that, while subject to all of the influences of winter, they are undergoing a change that carries them nearer to maturity. With the settled spring weather they eat a round hole in the straw and make their way forth. As males are few they rarely pair, if at all, but are ready to begin oviposition as soon as out of the straw. They

[a] Report U. S. Comm. Agr. 1886, p. 573, footnote.

[b] Grass and Grain Joint-worm Flies and their Allies, Tech. Ser. 2, Div. Ent., U. S. Dept. Agr.

are, except in rare cases, entirely devoid of wings, and migration is therefore out of the question, except for short distances.

OVIPOSITION OF THE SPRING FORM (MINUTUM).

At the time that the minute, wingless females that comprise this form appear in spring the young wheat plants are only starting to throw the stem upward, and if one will take the trouble to cut one of them directly through the center, longitudinally, he will be able to observe the embryo head not far above the surface of the ground. Pushing its ovipositor through the stem to the center, the mother insect places her egg in the embryo head, which is not only the most vital part of the plant, so far as the fruitfulness thereof is concerned, but where her offspring will be in the midst of the most tender and highly nutritious food possible. As a result of this the young head is destroyed and further growth of the stem prevented. In some instances the young larva is itself destroyed before it has finished its destruction of the head, and a distorted wheat head supported by a dwarfed and weakly stem is the consequence. One of these partly destroyed heads is illustrated in fig. 5. In most cases the stem ceases to grow, withers up, and dies, though usually standing upright, at the height of from 1 to 6 inches, with the leaves drooping down about the stem, both dead and discolored. In feeding on the young head the larva forms a cell-like cavity which, owing to the size of the larva and pupa, sometimes takes on a somewhat gall-like appearance, not noticeable except when cut in two. It would seem that the superior article of food which nature provides for these larvæ might to some extent account for the larger and more robust adults which constitute the second or summer brood. The larvæ must develop quite rapidly, as,

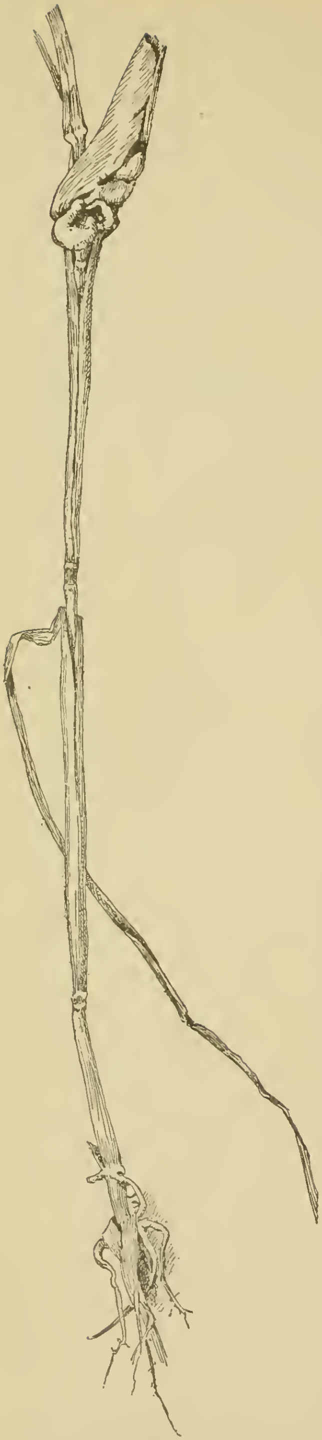

FIG. 5.—Head of wheat partially destroyed by *Isosoma minutum* (drawn in Division of Entomology).

by June 10, nearly all have transformed to the adult summer form (*grande*), which begins to appear about June 1, reaching its maximum in point of numbers about June 20, though I have found an occasional individual as late as the 27th of that month. In ovipositing, *minutum* seems to prefer the lateral stems in which to place her eggs, thus leaving the central stem unaffected. With the summer form (*grande*) this selection is reversed and the largest and most thrifty stems are selected. Spots of rank growing, thinly placed grain will suffer worse than the more densely growing areas.

OVIPOSITION OF THE SUMMER FORM (GRANDE).

Nurtured in the midst of the embryo head, we would naturally look for an adult insect differing somewhat from the one developing from larvæ whose food is of a coarser and tougher nature, and in this case, whether as a coincidence or otherwise, we have a much larger insect with fully developed wings, forming in consequence the migratory brood of the species. That these females wander about from field to field is shown by the fact that they may be captured during June by sweeping over the grass lands with an ordinary insect net, such as is used by entomologists for this purpose.

The method of oviposition between the spring and summer forms does not differ materially, except as the difference in the conditions of the plant makes slight variations necessary. The former must place her eggs in the very young plant comparatively close to the surface of the ground, while the latter seems to try to get her egg immediately above the uppermost joint of the wheat stem within her reach. At the season of the year when this takes place the upper, and frequently the joint next below, is not uncovered by the leaves and sheath, but the majority of the eggs are placed, singly, just above either the second or third joint below the head, and rarely above the upper joint. The significance of this to the farmer is that very few of the larvæ hatching from these eggs will be taken away with the straw, but, on the contrary, left in the field in the stubble. If the reverse were the case, and most of the larvæ removed with the straw to the barnyard, there to be either run through the stables or similarly utilized, in most cases hardly an individual would get back into the wheat fields in spring, for it must be remembered that at this period the adults are wingless and incapable of flying. The method of oviposition is shown in fig. 6, *a*, and the point where the egg is deposited in the straw is shown in figure 6, *b*, the transverse line showing the track of the ovipositor. To place her egg, the female takes up her position just above the joint, with her head downward. She then straightens her legs, thus throwing her body away from the stem, at the same time bringing her feet almost directly beneath the body. She now brings the abdomen downward and forward between her legs, much as a bee would do if alighting and instantly stinging an animal. The next move is to let the tip of the abdomen strike the stem and then go back to its proper position, but the tip of the ovipositor does not; on the contrary, it catches on the surface of the stem, directly beneath the body of the insect, and by putting its machinery in motion and drawing the stem toward her she slowly forces the ovipositor into the soft, juicy stem at the point where this is solid and not hollow, as is the case a short distance above and immediately below the joint. The tip of the ovipositor is composed of two flattened plates arranged side by side, the edges of which are sharp, and are propelled with a sort of rotary motion alternating with each other. In this way the ovipositor cuts and drills its way to the center of the stem, and an egg is forced down the interior and left in its proper place in the stem of the plant. The female recovers her ovipositor by again straightening her legs and pushing the plant from her. Only one egg is placed in the same location, though perhaps more than one is placed in the same straw by the same female, but if so they are placed above different joints in the straw. The larvæ must mature quickly, for, though pupation does not take place until about October, the stem ripens and becomes tough and woody, wholly unfit for the food of the larvæ, within less than a month. It would seem that the mother insect is aware of this, as she invariably selects the greenest and rankest growing plants in the more open spots, where the straw matures the slowest and remains green and juicy the longest.

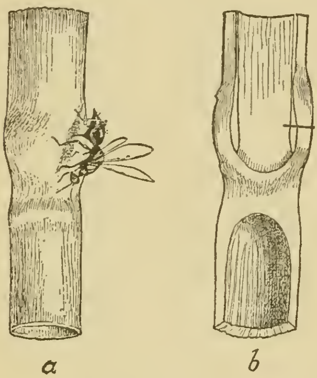

Fig. 6.—Method of oviposition of female of summer form (*Isosoma grande*, Riley): *a*, female inserting her eggs; *b*, section of wheat stem showing point reached by oviposition (after Riley).

Briefly, then, the insect passes the winter in the stubble—with the exception of the few that have been removed with the straw—in the pupal stage. In late March or during April the spring form (*minutum*), small, jet-black, ant-like, and with rare exceptions wingless females, eat their way out of their winter home and seek the young growing wheat plants. They deposit their eggs singly, placing them in the embryo head. These hatch within a few days and the larvæ mature and transform to the form *grande*, large, robust, also jet-black, with fully developed wings, in late May and the first two-thirds of June. These last are also females, and without pairing they begin to deposit their eggs in the now nearly fully developed straws. The eggs are placed just above the uppermost joint accessible to the female, usually the second or third below the head. But a single egg is deposited in a place, the object of the mother insect seeming to be to get it in the center of the stem in the more or less solid portion just above the joint. The eggs, as with those of the spring brood, hatch in a short time, and the larvæ reach maturity by the time the straw has become too tough and dry to afford further nutriment. The larva at this time usually gnaws its way down into, or at least partly into, the joint, and without forming cell or cocoon, about October passes into the pupal stage.

DESCRIPTION.

ADULTS OF SUMMER FORM.

(*Isosoma grande* Riley.)

Length of body, 4.2 mm.; expanse, 7.6 mm. Antennæ rather more slender and less clavate than in the spring form and but half the length of the thorax. Thorax with the mesonotum slightly more rugulose; wings larger and less hyaline than in the winged specimens of the spring form, with the veins extending to the outer third, the submarginal nearly four times as long as the marginal; legs with the femora less swollen. Abdomen not so long as the thorax, stouter than in the spring form, ovate-acuminate, approaching typical Eurytoma. Less hairy than in the spring form, especially about the legs, the hairs about the abdomen being less numerous, less regular, and shorter. Coloration similar to that of the spring form, but brighter and more highly contrasting, the promotal spot larger and brighter yellow, the pedicel of the antennæ yellow, and the femora with a definitely limited suboval yellowish spot below, near the tip, extending two-fifths the length of the femur on front pair, smaller on middle pair, and still shorter and less definite on posterior pair.

Larva greenish yellow in color. Average length, 6 mm.; otherwise of same proportions and structure as in spring form.[a]

Pupa, average length, 5 mm. Except in larger size and ample wingpads undistinguishable from that of the spring form, *minutum*.

Egg of the ordinary ovoid form with pedicel about twice as long as the bulbous part. The apical end is furnished with a distinct hook, perhaps for the purpose of holding the egg in place while the ovipositor is being withdrawn from the plant.

ADULTS OF SPRING FORM.

(*Isosoma minutum.*)

Length of body, 2.8 mm.; expanse of wings, 4 mm.; greatest width of front wing, 0.7 mm.; antennæ, subclavate, three-fourths the length of thorax; whole body (with exception of metanotum, which is finely punctulate) highly polished and sparsely covered with long hairs toward the end of abdomen; abdomen longer than thorax and stouter. Color, pitchy black; scape of antennæ, occasionally a small patch on the cheek, mesoscutum, femoro-tibial articulations, coxæ above and tarsi (except last joint) tawny; pronotal spot large, oval, and pale yellowish in color; wing veins dusky yellow and extending to beyond middle of wing; submarginal three times as long as marginal; postmarginal very slightly shorter than marginal, and stigmal also shorter than marginal. (See Riley, Am. Nat., 1882, p. 247.)

Larva, length, 4.5 mm.; of the shape indicated in fig. 3; color pale yellow; mouth parts brownish. Antennæ appearing as short two-jointed tubercles. Mandibles with two teeth. Venter furnished with a double longitudinal row of stout bristles, a pair to each joint. Each joint bears also, laterally, a short bristle. Stigma pale, circular; ten pairs, one on each of joints 2 (mesothoracic) to 11.

Pupa, jet black without other coloring; smaller than that of summer form. That is to say, the pupæ wintering over in the straw and from which the spring form develops is thus to be described; that following the larvæ developing in spring is understood to belong to the summer form.

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[a] Riley, Ann. Rept. U. S. Dept. Agr., 1884, p. 58.

NATURAL ENEMIES.

Probably the most efficient enemy of this species is a small, slender, four-winged fly, of somewhat brilliant metallic-colored body and yellow legs. This has a very slight resemblance to an Isosoma, and, indeed, was described as *Isosoma allynii*, now known as *Eupelmus allynii* French. A somewhat similar insect with metallic body and yellow abdomen, *Stictonotus isosomatis* Riley, is very efficient in destroying the larvæ in the straw. *Homoporus* (*Semiotellus*) *chalcidephagus* Walsh and beyond a doubt other chalcids are also instrumental in holding it in check. These parasites are all the more efficient as they are double-brooded also, developing in late summer and at once ovipositing in other larvæ. There is also an egg parasite that I have reared in connection with Isosoma, but not with certainty from this species. This is *Oligosita americana* Ashmead MS. As in all cases where I have obtained this there were species involved other than the one under consideration, it is obviously impossible to say that it destroys the eggs of this species, but with such regularity does it occur in connection with Isosoma in general that no doubt it preys upon this one with the others. When the wheat is harvested the straw is frequently, and, in fact, almost invariably, cut off between joints, thus leaving the larvæ, if there are such in the straws at that point, exposed to attack from predaceous insects. The larvæ of a small, slender, black and yellow carabid beetle (*Leptotrachelus dorsalis* Fab.) crawls up, descends into the stubble and devours the Isosoma larvæ, but unfortunately its taste seems to be too obtuse to allow it to confine itself strictly to Isosoma, and as a consequence it devours parasites as well as host. The mite *Pediculoides* (*Heteropus*) *ventricosus* (fig. 7) is also an enemy, gaining access to the larvæ precisely as with the beetle larvæ previously mentioned.

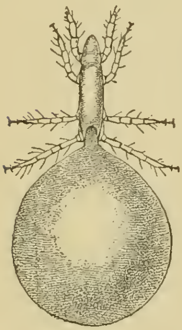

FIG. 7.—*Pediculoides ventricosus* Newp., a mite which destroys the larva—much enlarged (after Marlatt).

PREVENTIVE AND REMEDIAL MEASURES.

The fact of the spring brood being almost entirely wingless and therefore unable to fly from field to field places it almost totally at the mercy of the farmer, as he has but to change his crop from one field to another to rid himself of its presence. It is true the summer form can fly about from field to field at will, and it does so, but if the spring brood of adults are left helpless in a field with no wheat plants in which to place their eggs, it will be seen at once that there can be no summer brood emanating from this source. Rotation of crop will as a consequence be sufficient to prevent an overabundance of this species. But there are conditions under which this is not practicable, as in some sections and with some farms the soil is but little fitted for other crops, and where wheat follows wheat year after year for an indefinite period. Under such conditions, burning the stubble before preparing the ground for the new crop in fall will prove effective. If this burning is delayed until September, many of the parasites will have developed and escaped. The burning can be best carried out by cutting the grain as high as possible, leaving the stubble long. A few days before burning a mower should be run over the field, cutting off all grass and weeds, which, when dried, will add to the fuel supplied by the stubble. Taking advantage of a favorable wind, the farmer can burn over his field cleanly, thereby not only ridding it of the presence of this pest, but also the Hessian fly, besides burning up much of the seed of foul weeds and grasses.

DISTRIBUTION.

This species seems to occur throughout the middle belt of country from the Atlantic to the Pacific, wherever wheat is grown as a staple crop. Whether it is single-brooded in the North and is, therefore, in such countries capable of sustaining itself in spring wheat, is not yet known. Having no other known food plant than wheat, it will necessarily follow that its range will be restricted to areas of wheat cultivation, and being double brooded, requires fall wheat in which to develop. The fact of its having been so long confused with what now seems the true joint-worm fly (*Isosoma tritici* Fitch) renders its actual distribution, as well as the extent of its ravages in the past, somewhat obscure. I found the summer form (*grande*) in considerable numbers in spring wheat at Lafayette, Ind., June 19, 1895, and it is likely that it can breed therein, though fall wheat is necessary for form *minutum*.

THE JOINT-WORM.

(*Isosoma tritici* Fitch. Figs. 8 and 9.)

I have previously referred to the confusion of *Isosoma tritici* Fitch with *I. hordei* Harris, and which was so persistently insisted upon by Walsh and Riley. It was not until 1896 that Dr. Howard succeeded in establishing the fact that this is a valid species, and now we are confronted with a long series of complications that can only be safely corrected by carefully rearing both species and studying them anew. Failing entirely in securing sufficient material from wheat in carrying out the investigations upon which this bulletin is based, I feel now very much like letting the insect alone until an opportunity is offered to untangle the knotted skein. Doctor Fitch stated distinctly that the term "joint-worm" was to be applied to the insect attacking wheat, and it was because of the mistake of considering it the same insect as that described by Harris that the name "joint-worm" came to be applied to *I. hordei* at all; a mistake that belongs neither to Harris nor Fitch, but one that has misled nearly everybody.

PREVIOUS RECORD OF THE INSECT.

About the year 1848, in central Virginia, throughout the country adjacent to Charlottesville, Albemarle County, and Gordonsville, Orange County, the wheat began to suffer seriously from attack of what was at that time called the joint-worm. In 1851 the wheat in Albemarle County was, much of it, not worth the harvesting. In 1854 the ravages of the pest had become so serious that a "joint-worm convention" was held in Warrenton to devise means for controlling it and preventing, if possible, its further ravages, as by this time it had become almost impossible to raise wheat at all in the infested territory. The action of this convention was to recommend a better system of cultivation, the use of guano and other fertilizers to promote the rapid growth and early ripening of the grain, and the burning of the stubble after harvest.

FIG. 8.—*Isosoma tritici* Fitch: adult of the joint-worm, much enlarged (from Howard).

Looking back to this period, our later-day entomologists can hardly understand how there should have been any difficulty in determining beyond a possible doubt the author of all of this destruction. Doctor Fitch, who, it seems, received some of the growing wheat plants infested with the larvæ from that locality, always insisted that he found a cecidomyian larvæ inhabiting cells like those occupied by the joint-worm and that these were the true depredator, and, though he continued to stoutly defend his determination, we have yet to discover a Cecidomyia either causing or inhabiting such a cell or gall in the wheat plant. From all that has been since learned relative to these insects it is clear that the ravages were those of this species, with, perhaps, individuals of the preceding species intermixed among them. As a matter of history it may be stated that Doctor Fitch was still unconvinced that the joint-worm, and not a dipterous insect, was responsible for the damage in Virginia as so late as 1859 he expressed astonishment that he was unable to rear any Hessian flies from the same straw from which he reared the joint-worm. Surely the unentomological farmer might be pardoned for falling into the same error until, at least, he is placed in possession of some way of distinguishing them from each other.

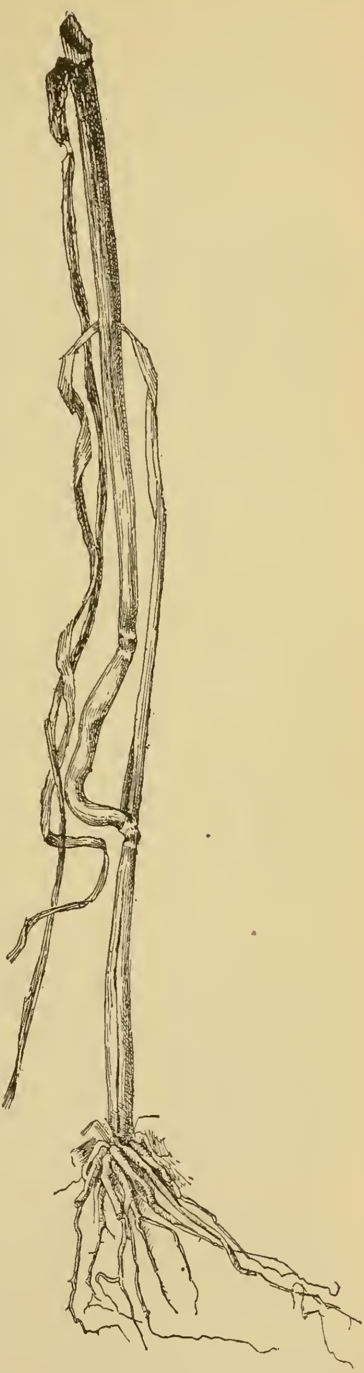

Fig. 9.—Effect of joint-worm in wheat straw (drawn in Division of Entomology).

After finding out beyond question that this is a valid species, that it is the true joint-worm fly attacking wheat and not barley, while *Isosoma hordei* attacks barley and not wheat, notwithstanding the effect on the straw is much the same, and that though it resembles *Isosoma grande* rather closely, it is quite different in habits and life history, we are forced to conclude that we really know very little about it. I have reared it in limited numbers from wheat straw in Illinois, Indiana, and Ohio, though it would appear that about 1885 it became excessively abundant in some parts of Michigan, and, in fact, I am not sure but that I have myself found the larvæ in some abundance, but supposed them to belong to the preceding species. The uncertainty in regard to the identity of these larvæ was owing to the fact that at the time they were observed this was not considered a valid species, and I at that time considered them as belonging to *Isosoma grande*, but now doubt my former opinion from the fact that this species does not always form galls either in wheat or Elymus, that there were several larvæ between the joints instead of one, and that they were located just under the inner walls of the straw, but not forming a cell, whereas those of the species last considèred is found only in the center of the straw, in the more solid substance, immediately above the joint itself. In 1885 Professor Cook described *Isosoma nigrum*, which he states was reared from larvæ forming creases and hardened deformities in the straw. Professor Cook's specimens, sent to Washington, have been determined by Doctor Howard as *Isosoma tritici* Fitch.[a] (See also Walsh, Trans. Ill. St. Agl. Soc., vol. 5, pp. 485–490, figs.)

LIFE HISTORY.

The larvæ pass the winter in the straw, if in wheat, and in the stems of Virginia rye grass (*Elymus virginicus*) in the East, and *E. glaucus* and another grass, either *Bromus ciliatus* or a species of Agropyron, in California.

In the Middle West the adults appear the latter part of May and early June. The egg does not differ materially from that of *I. grande*, and it is probable that the method of oviposition is much the same as in that species, the female placing her eggs in the young growing wheat plant just above the uppermost joint to which she can secure access at the time. Ordinarily the upper joint is not yet uncovered, except in case of very early wheat, and in that which has made less advance even the second joint from the head is so covered with the sheaths that the insect is unable to determine its position, so that sometimes we find more larvæ between the second and third joints than we do farther up between the first and second, precisely as with *I. grande*. The larvæ reach their full growth by harvest, but do not pupate until the following spring.

All adults are winged, and both sexes are represented. Outside the wheat field I have reared the insect only from *Elymus virginicus*, and I question its breeding in the stems of cheat (*Bromus secalinus*) for the reason that I have reared it from the rye grass and not from the cheat, though both were abundant in the same locality. Mr. Koebele, who reared it from *Elymus glaucus* in California, was uncertain whether he also reared it from *Bromus ciliatus* or Agropyron. Both the Bromus mentioned by Koebele and *Agropyron repens* occur in the East, and it is very probable that future studies of the species will show that there are other grasses besides rye grass that will require attention from the farmer who wishes to guard against its appearance in his fields by preventing its breeding permanently along roadsides and the borders of his fields.

DISTRIBUTION.

Doctor Fitch received this insect from Maryland, Doctor Lintner and Professor Comstock reared it in New York, the United States Department of Agriculture has it from Virginia and North Carolina, Professor Cook reared it in Michigan, I have reared it in Ohio and Illinois

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[a] Grass and Joint-worm Flies and their Allies, Tech. Ser. 2, Div. Ent., U. S. Dept. Agr., p. 18.

and found it in Indiana, Doctor Fletcher has reared it in Ontario, Canada, and Mr. Koebele in California, and there is hardly a doubt that investigations will reveal its presence throughout the entire wheat-growing region of North America. Being fully winged and single brooded, as well as capable of breeding in abundance outside of the grain fields, there seems no good reason why it should not cover the whole country, attacking either spring or winter wheat.

DESCRIPTION.

"*Female.*—Length 4 mm.; expanse 7.6 mm. Head, pronotum, and mesonotum strongly rugulose but not umbilicate-punctate except toward tip of scutellum, where an occasional umbilicate puncture occurs; metanotum also strongly rugulose, with a faint trace anteriorly of a median longitudinal furrow; metanotal spiracles large and perfectly circular; pronotal spots moderately large and often faint, but plainly discernible from above, sometimes, however, quite bright and distinct. Abdomen longer than thorax, nearly as long as head and thorax together; abdominal segments 4 and 5 together longer than 2, 3 only about half as long as 4, and 5 as long as two preceding united; first funicle joint one-half longer than second; club longer than three preceding funicle joints together. Body slightly but plainly pilose except at sides of metanotum, where the fimbria is very obvious. Legs black except at joints, which, with the tarsi, are yellow. Claw of stigmal club given off before the tip.

Male.—Length, 2.9 mm.; expanse, 6 mm. Petiole shorter than hind coxæ, faintly punctate; flagellum of antennæ uniformly pilose, joints well rounded above, not strongly pedicellate; joint 1 three times as long as wide and nearly three times as long as pedicel; none of the funicle joints constricted in the middle; joints 2 and 3 each nearly as long as 1; joints 4 and 5 each a little shorter; club plainly divided by a distinct incision into two joints, but the terminal ovate joint is not pedicellate." Howard, Tech. Ser. 2, Div. Ent., U. S. Dep. Agr., pp. 17, 18.

Originally described by Fitch, Jour. N. Y. State Agr. Soc., 1859, p. 115. Cited as *Isosoma hordei* by Walsh, Amer. Ent. and Bot., II, p. 332. Described as *Decatoma basilaris* by Provancher, Faun. Ent. Can., II, p. 569.

NATURAL ENEMIES.

The natural enemies are, with few exceptions, probably the same as with the preceding species, to which this is more closely related than with the one that follows, at least so far as its life history is concerned. In my own rearings I have invariably bred this in connection with *I. grande* if from wheat straw, or with *I. elymi* if from grass, so that personally I am not able to say that certain parasites actually came from *I. tritici*, though there is no reason for doubting that such was the case. Certain parasites do most certainly confine themselves to particular species of Isosoma. *Websterellus tritici* Ashm. has only been reared from this species, as it is now known. An undescribed Isosoma occurs in considerable abundance in the stems of *Tricuspis seslerioides*, and from this I have reared a parasite belonging to the genus Torymus, but strangely enough this parasite has only been reared from this particular Isosoma, even where the grass infested by its particular host was growing in the midst of Elymus, literally alive with the larvæ of three other species of Isosoma. Thus, while some parasites attack all of the species, there are evidently others that restrict themselves to one.

REMEDIAL AND PREVENTIVE MEASURES.

Owing to its possessing wings whereby it is capable of flying readily from one field to another, or breeding in the stems of grasses in the intervening territory, a rotation of crop will be less effective in the case of this species than with the preceding. For the same reason, careful attention to roadsides, borders of fields, and ditches becomes all the more imperative. The burning over of the stubble fields before preparing the ground for wheat again in the fall, or the same treatment of the uncultivated areas above mentioned at any time during winter or early spring will effectually exterminate these insects where these measures are carried out. In the Middle West wheat seldom follows wheat on the same ground for a series of years, the grain being rotated with red clover, which prevents the burning over of the stubble fields in the fall, but does not in any way affect the treatment of grass lands, and if the crop is rotated annually and the borders and waste places attended to there is little likelihood of the farmer suffering greatly from the depredations of this insect. I have invariably found the most serious injuries to occur on thin or poorly fertilized soils or where the land had not been thoroughly prepared before seeding. Probably whatever tends to produce a healthy, vigorous growth of the wheat plant will tend to discourage oviposition by the insect. It is not known that the insect prefers one variety of wheat to another, but the variety with the stoutest straw will probably suffer least from attack.

DIFFICULTY IN RECOGNIZING THE SPECIES.

I have made no attempt to describe the larva and pupa in their proper place, because I do not believe they can be separated by any description from those of the preceding species if in wheat, or those of *Isosoma elymi* French if in grass. Notwithstanding this the farmer can readily separate them at the proper season of the year, even if both are present in his cultivated fields. After October this species will be in the form of a yellowish white larva in the stubble, while the preceding species will be in the form of a black pupa, both perhaps in the center of the stubble. In spring the larvæ of this species will change to a jet black pupa, while those of *I. grande* will have developed and escaped. So, then, pupæ found in the fall will probably belong to the preceding species; those found in spring, if in wheat, to this, and larvæ found after October, if in wheat stubble, also to this species. However, too much reliance must not be placed on these distinctions, as there are other supposed species of these insects attacking wheat of whose larvæ and pupæ we know nothing, but with our present knowledge the facts just given are the best that can now be offered the farmer in order to enable him to separate the different main enemies of his grain and receive whatever practical benefit is possible from what information is now available, leaving future studies to throw more light upon his problems. The adults can be easily separated from those of the preceding species by their smaller size, and from the next by their smaller size and the color of the legs, which in *I. hordei* are honey yellow. The larvæ are also smaller than those of the following species and may or may not cause galls and deformities in the straw. The adults of the summer form of the preceding and those of the following species are abroad at the same time as are those of this species during the last days of May and early June.

While fig. 9 illustrates the effect of the larvæ on a wheat plant, there are so many variations from this that it is at present impossible to separate these two gall-forming species by their effect on the straw.

THE BARLEY STRAW-WORM.

(*Isosoma hordei* Harris. Fig. 10.)

Up to 1896 this species was confused with the preceding and the term "joint-worm" applied thereto. The fact is, Harris seems not to have given this name to his species at all, but on the other hand Doctor Fitch applied it to his *I. tritici*, and it was owing to the confusion of these two insects that the name became misapplied, and I have here given Harris's species the name "barley straw-worm," in accordance with the name *hordei*.

PREVIOUS RECORDS OF THE INSECT.

Of all of our described species of Isosoma this was the earliest known and was for many years supposed to be the only species infesting cultivated grains or, in fact, inhabiting this country, as it was considered a parasite on the real depredator, presumed to be some kind of a two-winged fly, and was actually described by Dr. W. T. Harris in 1830 as a parasite, under the name *Ichneumon hordei*.[a] Doctor Harris certainly seems to have been aware of the fact that as early as 1821 Mr. James Worth, of Sharon, Bucks County, Pa., found larvæ clearly belonging to some species of Isosoma affecting the culms of wheat "near the root, where they caused enlargements of the stem;"[b] and in 1823, Mr. Joseph E. Muse, of Cambridge (Eastern Shore), Md., reared an insect, also from wheat, which he termed a

[a] New England Farmer, July 23, 1830; Ins. Mass., 1841, pp. 434–437.

[b] American Farmer, vol. 4, p. 394.

"Tenthredo," whose larvæ, as he stated, "burrow within the stems and feed upon them."[a] Doctor Harris, in the edition of 1841 of his Insects of Massachusetts, page 434, refers to the statement of Dr. Andrew Nichols, of Danvers, who stated that worms found in his barley straw were about one-tenth of an inch in length and of a yellow or straw color, and that in the month of November they appeared to have passed into the chrysalis state, but living through winter unchanged in the straw. The insects referred to by Mr. Worth, of Pennsylvania, and Mr. Muse, of Maryland, might quite probably have been *Isosoma tritici* Fitch, but if the one referred to by Doctor Nichols was an Isosoma at all it was certainly *I. grande*, as that is the only species attacking grain that is known to pupate in the fall. Thus it will be seen that it is not easy to determine just what Harris might have included as belonging to his *I. hordei*, though he nowhere states that it was ever obtained from any other than barley straw; hence the name, *hordei*, applied to it. It is interesting to know that specimens labeled in his handwriting "Parasitic in barley, June 15, 1830," are still in the museum of the Boston Society of Natural History, so that there can be no mistake in the identity of the insect described. Even in the edition of his Insects of Massachusetts, of 1841, Harris makes no mention of his species having been found affecting wheat. In the edition of 1852 he relates that about eight years before children sleeping on straw beds in Cambridge, Mass., had been bitten by these insects and the annoyance had been so great that the beds, both straw and ticks, had been burned. Now people do not use barley straw for such domestic purposes, nor in fact do they use wheat straw as a rule, but oat straw. As Doctor Harris does not enlighten us as to what kind of straw it was from which the insects annoying the children came, we still have no direct proof that this species was ever known in connection with wheat straw.

FIG. 10.—*Isosoma hordei* Harris: adult of the barley straw-worm (from Howard).

About 1852 there appeared a similar trouble in the barley in central New York, and though Doctor Fitch described it as a distinct species under the name *Eurytoma fulvipes*,[b] we now know that it was

[a] Loc. cit., vol. 5, p. 113.

[b] Jour. N. Y. Agricultural Soc., Vol. IX, p. 115.

Isosoma hordei. This last outbreak in central New York appears to have been rather widespread and disastrous, for in 1858 Hon. George Geddes, president of the State Agricultural Society, stated that while formerly a yield of 40 bushels of barley to the acre was expected, they could not at that time rely upon more than 20, and unless relief came barley growing, on account of the attack of this pest, would have to be abandoned.[a]

There was a local outbreak of this species in Ontario, Canada, in 1867–68, and observed at Wakeman, Chagrin Falls, and Barry, Ohio; Indiantown, Cuckoo, and Paynes, Va.; Albany, N. Y.; Canada West (William Couper); Ottawa, Canada; and Urbana, Carbondale, and Marshall, Ill. So far it has not been reported from the Pacific coast States. Doctor Fitch confined this species to the insect reared by Harris in Massachusetts, and the one working the injuries in central New York as *Isosoma fulvipes*, both of which are now known to belong to *Isosoma hordei.*

LIFE HISTORY

The species is single brooded. The adults of both sexes, all fully winged, emerge from the straw and grass in late May and early June, ovipositing almost immediately. The effect of the larvæ on the growing plants begins to show within a short time, and, though the larvæ become full grown during June and early July, they remain in this condition within their cells until May of the following year.

EFFECT OF THE LARVÆ ON THE PLANT.

The eggs may be deposited in the stem of barley or grass anywhere between the root and the head, even among the lower spikelets of the head. The effect of the larvæ may be to cause hard, woody cells, whose outline is indicated only by slight discolorations, the outer surface of the stem being smooth and not in the least swollen, the cell being entirely within the walls of the stem, causing no distortion in the straw; or there may be anywhere from one to a dozen galls in a cluster, and these may be either clearly defined or so packed together and cramped as to lose all semblance to the typical galls and take on the appearance of diminutive growths, resembling the black knot of the cherry and plum. The straw or grass stem may be enlarged to two or three times its natural size, forming an elongated oval woody growth that pushes its way outward, bursting, as it were, the sheath at base, and showing between the edges. This growth is usually on one side of the stem, just above the joint, and is marked with interlacing creases and furrows indicating the outlines of each individual cell, and in many cases sending downward from the lower extremity small root-like appendages, the use or cause of which it is difficult

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[a] Trans. N. Y. Agl. Soc., 1859, p. 332.

to understand. All of these malformations as well as others may be found in the stems of *Elymus canadensis* in abundance, from which swarms of the adults will emerge in late May and early June. Owing to the woody nature of these abnormal growths, straw attacked by this species is more likely to be broken up into small bits, and these go in with the grain at thrashing, thereby increasing the danger of transportation from one locality to another, but to offset that, as it were. there is likely to be a greater proportion of the insects left in the stubble than with the other species, as the affected straws are usually more stunted in growth and shorter. At present there is no other insect attacking wheat, rye, or barley that causes similar growths in the straw except *Isosoma tritici* Fitch, in wheat, and the farmer can hardly mistake the work of these two pests for those of any other in his fields.

DESCRIPTION.

"*Female.*—Length, 3.6 mm.; expanse, 6 mm. Pronotum and mesonotum minutely but strongly rugulose, smoother than *I. tritici*; metanotum more coarsely rugulose, the larger elevations taking a longitudinal direction, no central furrow or carina; pronotal spot very small, not visible from above. Abdomen as long as head and thorax together; joints 4, 6, and 7 subequal in length, the fifth a little longer; joint 3 a little longer than 4, 2 hardly longer than 3 and 4 united; funicle joints 2 to 5 submoniliform, but still a little longer than broad. All legs (except coxæ) and antennæ honey-yellow, flagellum and femora a little darker; claw of stigmal club straight, given off well before tip of club; pilosity sparse.

"*Male.*—The only males which I have seen are the two from the Harris collection. These are both in very bad condition; neither had an abdomen and one has no antennæ. With the other, but three funicle joints remain on the left antenna (the others being broken off) and four on the right, but the latter are still inclosed in the pupal sheath. The three funicle joints remaining on the left antenna are not pedicellate, very slightly arched above, and furnished with close, moderately short hair not arranged in whorls; joint 1 longest, 2 and 3 successively decreasing. Joint 4 is still shorter, judging from the sheathed right antenna." (Howard, Tech. Ser. 2, Div. Ent., U. S. Dept. Agr., pp. 18, 19.)

The foregoing description was drawn up from specimens in the Fitch collection, labeled, in Fitch's handwriting, "*Eurytoma fulvipes* Fh.;" other specimens from the Harris collection, reared from barley, June 15, 1830; other specimens from "Canada West," and still others reared by myself from stems of *Elymus canadensis* growing near Champaign, Ill. This is the *Ichneumon hordei* described by Harris in the New England Farmer, the *Eurytoma fulvipes* described by Fitch in his seventh report, and the *Isosoma hordei* mentioned by Walsh in the American Entomologist (Vol. II, p. 330).

The larva, except from its larger size and habit of living within a cell, is not distinguishable from that of the other species of grain-infesting Isosoma. It is little larger than that of *I. grande*, found in May and early June, and it has the universal yellowish-white color. The same may be said of the pupa.

NATURAL ENEMIES.

The larvæ appear to suffer more from the inroads of natural enemies than do those of other species of these insects, perhaps because of their inhabiting the walls instead of the center of the straws, thereby rendering them more accessible. It may be that this is the older form, and a greater number of the parasitic species have become adapted to it as a host insect. There is little doubt that *Oligosita americana* Ashm. and *Polyneura citripes* Ashm. both attack and destroy the eggs, as I have reared them in numbers from stems of Elymus inhabited by the larvæ, and also the stems of other grasses inhabited by other Isosoma larvæ. *Eupelmus allynii* French, easily known by its slender body, metallic color, with yellow legs, is associated with this as it is with nearly all other species of these insects that inhabit the stems of grain and grass. *Merisus isosomatis* Riley, conspicuous for its yellow body, is almost as abundant as the preceding, and, as the name implies, is parasitic on other species also. *Homoporus chalcidephagus* Walsh is also a parasite, but I have reared it in lesser numbers than the other two, in Illinois, Indiana, and Ohio. Almost the first parasitic species that I reared in connection with the present studies of *Isosoma hordei* was a second new genus and species, *Parapteromalus isosomatis* Ashmead MS. I have myself witnessed the oviposition of all of these parasitic species, and their life history is probably practically the same. The adults emerge in spring a little later than those of the Isosoma, but there is a second generation of adults in summer, and it is these that I have observed placing their eggs in the cells of *I. hordei*, thus doubling their effectiveness in holding it in restraint and preventing more frequent and greater devastations in the grain fields of the farmer. While carrying on the present investigation I have reared an undetermined Eurytoma, a parasite on Isosoma, but as I reared four species of the latter from the same lot of stems, it is impossible to say to what extent it preys upon the one now under consideration, nor do I know anything in connection with its habits, except that it makes its appearance in spring, simultaneously with other parasites.

PREVENTIVE MEASURES.

The preventive measures might well be summed up under the caption of good farming, for there is not one practical measure but will pay for its carrying out, aside from its entomological influences. As the adults are fully winged and can fly freely from one field to another, less must be expected from a rotation of crop, but even under these conditions, a certain amount of benefit will result from a careful system of crop rotation. Wheat, rye, or barley should never be grown on the same land for more than two years in succession without carefully burning over the stubble before preparing the ground for another seeding. To these must be added the mowing off of roadsides and along fences and margins of fields during late June or early July, or the burning over of these during winter or early spring, thus destroying the hibernating larvæ. The rye grass along the margins of fields and ditches should receive special attention in the matter of mowing and burning. It is not known whether or not anything is to be gained by early sowing, which, besides, is apt to invite the attack of Hessian fly.

THE CAPTIVE ISOSOMA.

(*Isosoma captivum* Howard. Fig. 11.)

Very little is known of the habits and transformations of this species. I found it in a field of growing rye near Normal, Ill., May 10, 1884, and swept it from timothy and bluegrass about Lafayette, Ind., during May, 1885, and again during the same month in 1886. Dr. J. A. Lintner reared both sexes from wheat straw sent him from Johnsons Creek, Niagara County, N. Y., in December, 1887, the adults appear-

FIG. 11.—*Isosoma captivum* How.: adult (from Howard).

ing in March of the following year, the straw having, presumably, been kept indoors during the winter.[a] Probably the adults occur normally at about the same time as those of *Isosoma hordei*, *tritici*, and *elymi*. We know that it attacks wheat, probably rye, and perhaps barley.

DESCRIPTION.

"*Female.*—Length, 3.4 mm.; expanse, 5.8 mm. Head and mesonotum uniformly, finely, and closely rugulose, not shagreened; metanotum more coarsely rugulose and with a narrow and shallow central longitudinal groove, which widens slightly posteriorly; pronotal spot plain, moderately large; hind coxæ delicately punctate.

[a] Fourth Report, State Entomologist of New York, p. 34.

Abdomen shiny, as long as thorax, oblong-ovoid; the second segment occupying nearly one-third the whole surface; segments 4 to 6 subequal, the third a little shorter; funicle joints 2 to 5 subequal; club nearly as long as three preceding joints; joint 1 one-half longer than 2; pile sparse and short, more marked at metanotal fimbria and terminal joints of abdomen than elsewhere. Color uniform black, except for pronotal spot, tarsi, middle and hind femoro-tibial knees, front tibæ and apical third of front femora, which are light honey yellow. Stigmal club about as in *I. hageni* and *I. agrostidis*, except that its tip is more rounded instead of squarely truncate.

"*Male.*—Length, 2.5 mm.; expanse, 5 mm. Punctation rather finer than with female; petiole as long as first abdominal joint, strongly rugose; flagellum of antennæ long; pedicel not globose, slightly elongate; joint 1 of funicle longest, twice as long as pedicel; joints 2, 3, 4, and 5 each a little shorter than its preceding joint; not so strongly pedicellate as with *I. californicum* and *I. bromi*, moderately arched above with hairs arranged in two indefinite whorls; club separated into two subequal pedicellate joints, giving the funicle the appearance of being 6-jointed instead of 5-jointed, as with *bromi* and *californicum;* scape short, about as long as pedicel and first funicle joint together; strongly expanded below tip. Coloration like that of the female." (Howard, Tech. Ser. 2, Div. Ent., U. S. Dept. Agr., pp. 13, 14, 1896.)

The earlier stages of development are unknown, but they probably differ little from those of allied species. Quite likely the same natural enemies prey upon it and the same repressive measure will apply to it as with the preceding species.

WEBSTER'S ISOSOMA.

(*Isosoma websteri* Howard. Fig. 12.)

This is in all probability a wheat-infesting species, as I found it in a wheat field near Bloomington, Ill., May 9 and 11, 1884, and about Lafayette, Ind., also in fields of wheat, June 2 and 16, 1885. I also

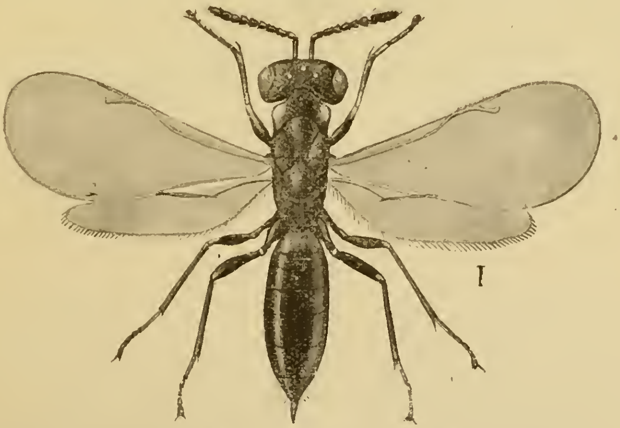

FIG. 12.—*Isosoma websteri:* adult female—much enlarged (from Howard).

reared it from a pupa taken from a growing wheat plant in the Bloomington, Ill., field May 29, but have not encountered it since in my studies of these insects. Nothing is known of its life history except what I have just given. Its close resemblance to *I. maculatum*, which I have reared from stems of cheat from the vicinity of Champaign and Urbana, Ill., is quite suggestive, the adults of this last species being abroad during late May and early June in the same localities.

DESCRIPTION.

"*Female.*—Length, 3.4 mm.; expanse 6.3 mm. Head, pronotum and mesonotum as with *I. maculatum;* metanotum with only the beginning of a central furrow, its lateral carinæ immediately curving around the sides, each inclosing an oval, flattened, nearly smooth portion of the metascutellum; a median carina extending nearly to the tip of the sclerite; pronotal spot moderately large and plainly seen from above, occupying a little more than one-third of the dorsal aspect of the pronotal foreborder. Abdomen much longer than the thorax; segments 3 to 5 increasing in length; 6 and 7 as long as 5. Antennæ with joint 1 of the funicle twice as long as 2; joints 3, 4, and 5 gradually decreasing in length, subequal in width; joint 5 more closely connected with club than with the preceding joint. Color and wing venation as with *I. maculatum.*" (Howard, Tech. Ser. 2, Div. Ent., U. S. Dept. Agr., pp. 15, 16, 1896.)

While, as stated, this is probably a wheat-infesting species, it is to be remembered that it has been reared only in a single instance, and it is within the range of possibility that my growing wheat plant, as I supposed, might possibly have been cheat, as it is easy to confuse the young plants, and as the two grow everywhere intermixed in the fields mere collecting offers no solution of the problem whatever. Of the four species of *Isosoma* which I have reared from common cheat (*Bromus secalinus*), viz, *I. elymi*, *I. albomaculata*, *I. hirtifrons*, and *I. maculatum*, none were found in the wheat straws growing in the same field.

Should the species become numerous enough to cause serious depredation it will probably yield to the same repressive measures as the other grain-attacking forms.

THE HAIRY-FACED ISOSOMA.

(*Isosoma hirtifrons* Howard. Fig. 13.)

The type specimens of this species were reared from rye straws collected by Mr. Coquillett, in Mercer County, Cal., in 1885. It was reared by myself from stems of common cheat growing in a wheat field near Urbana, Ill., in 1902. I know nothing whatever of its life history except that it appeared in my breeding cages in common with the other cheat-infesting species. The records of the Illinois State Laboratory of Natural History and those of the office of the State entomologist contain numerous references to Isosoma attacking rye.

Specimens of the affected straws show that a part of this injury was due to *Isosoma tritici*, whose presence could be detected by the larval cells in the walls of the straw; also many straws were attacked by a noncell-making species, the larvæ being in the center of the stems immediately above the joint. No adults were reared, as the larvæ were supposed to be those of the old *Isosoma tritici* Riley, which is not now known to attack any grain except wheat. It is therefore impossible to say which of the species whose larvæ live in the center of the stem it was that did the injury in these cases. I made every effort to secure material from the fields of rye about Urbana and Champaign, Ill., during the summer of 1902, but was unable to find any infested straw, and therefore can throw no light upon the identity of the rye-attacking species; but the fact that the one under consideration is known to affect rye in California would place it under

FIG. 13.—*Isosoma hirtifrons* How.: adult female, much enlarged (after Howard).

suspicion wherever it occurs in the eastern States. I judge that it will be very easily confused with other species, and the fact of its infesting cheat would lead to the suspicion that it will be found infesting other grasses.

DESCRIPTION.

"*Female.*—Length, 3.7 mm.; expanse, 7 mm. Sculpturing of head, pronotum, and mesonotum as in *I. websteri*, except that there are sparse, large, shallow punctures on the mesoscutellum; cheeks much fuller than in other species; metanotum as with *I. maculatum*. Abdomen about as long as thorax; segments 3 to 6 increasing in length. Antennæ stout, moderately long, very hairy; proportions about as in *I. websteri*. Body not unusually pilose, except face, which is closely covered with short white pile; pronotal spots very plain, but not large, occupying about one-third of the dorsal aspect of the fore-border of the pronotum. Color black, except for all femoro-tibial knees and pronotal spot. Claw of stigmal club given off some distance from tip, delicate and short." (Howard, Tech. Ser. 2, Div. Ent., U. S. Dept. Agr., p. 16, 1896.)

Up to the present time cheat has been looked upon only as an undesirable plant growing among wheat like weeds among corn, but it now appears to be doubly undesirable on account of its harboring insect enemies of cultivated grains.

ISOSOMA SECALE Fitch.

This was described by Doctor Fitch in 1861, after he had become fully convinced that these insects were not parasitic but the true depredators among grain.[a] I have not myself encountered it in the study of grain insects, but from the statements of Doctor Fitch it does not seem to differ in habits from *Isosoma hordei* and *I. tritici*, and one can not help suspecting that a careful study of its life history and development will show that it is one of these species. It was given the common name of "rye fly," and adults were reared from straws grown in 1860, emerging about the 1st of June, 1861. The larvæ were found to occupy cells in the walls of the rye straw, and not in the base of the sheaths, as was supposed to be the case with *I. hordei*, though Doctor Fitch describes "the disease which the insect causes in the rye being in every particular like that in barley and wheat." As we now know, barley and wheat are attacked by two different species, but all three seem to have precisely the same life history, so that whether there be one species or more, the farmer will be able to meet it or them with the same preventive measures.

DESCRIPTION.

"*Female.*—Length, 3.6 mm.; expanse, 6.6 mm. Punctation as with *I. hordei;* pronotal spot large, plainly seen from above. Abdomen as long as head and thorax; segments 4 and 5 subequal; 6 and 7 together shorter than 5; 2 much longer than 4 and 5 together. Color black; scape and legs black; front tibiæ, knees, and tips of middle and hind tibiæ and all tarsi honey yellow; claw of stigmal club given off near tip of club, somewhat curved; antennæ as in *I. hordei.*

"*Male.*—Length, 3 mm.; expanse, 5 mm. Specimen in poor condition. Expansion of scape more abrupt from tip than with other males described; funicle joints well arched above, scarcely pedicellate, each with 2 indefinite whorls of hair and with no median constriction; each joint twice as long as wide; club plainly divided into two joints, but no trace of pedicel to terminal joint, resembling *I. hordei* in this respect; petiole a little shorter than hind coxæ and shorter than first abdominal segment." (Howard, Tech. Ser. 2, Div. Ent., U. S. Dept. Agr., p. 19, 1896.)

In this connection it may not be out of place to state that I have reared an undetermined species of Isosoma in connection with *I. hordei* from the stems of *Elymus canadensis*, growing near Champaign, Ill., and seeming to affect the grass much in the same manner as

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[a] Seventh Report Noxious and other Insects of New York, pp. 849–851.

that species. It may on further study prove to have some connection with the one now being discussed, though I have not found it attacking rye.

FITCH'S ISOSOMA.

(*Isosoma fitchii* Howard.)

This is the last of the described Isosomas known to attack growing grain, though I have reared what appears to be still another from wheat straws from Carbondale, Ill.; but the specimens are still undetermined and nothing definite can now be said of them. This species was described from 2 females and 1 male found in the Fitch collection, labeled in Fitch's handwriting, "*Eurytoma hordei* Harris, Nos. 15223 and 15197." Nothing whatever is known of its habits, but it was presumably reared, with some other species, from grain.

DESCRIPTION.

"*Female.*—Length, 3 mm.; expanse, 5.8 mm. Head, pronotum, and mesonotum faintly shagreened, nearly smooth, shining; mesoscutellum with a few sparse punctures; metanotum with a complete median longitudinal furrow emarginate on the anterior half and with a central carina extending nearly to tip; very coarsely rugulose either side of the furrow with a faint granulation between raised lines; pronotal spot large, plainly seen from above, and two spots together occupying about one-third of the dorsal aspect of the foreborder of the pronotum. Antennæ with well-separated joints; funicle joints 2, 3, 4, and 5 equal in length and width; joint 1 a little longer; joint 5 as well separated from the club as from preceding joint; club a little longer than 4 and 5 together, but of the same width. Abdomen as long as the thorax; joint 4 shorter than 6; 5 longer than 6; 7 and 8 subequal. Color black, except for pronotal spot and knees, which are luteous; claw of stigmal club given off about at tip of club, straight.

"*Male.*—Length, 2.2 mm.; expanse, 4.2 mm. Petiole about as long as hind coxæ and nearly equal in length to first abdominal segment. Antennæ with funicle joints very slightly arched above, each joint fully three times as long as wide, and slightly constricted in the middle; otherwise as with *I. hordei*." (Howard, Tech. Ser. 2, Div. Ent., U. S. Dept. Agr., p. 20, 1896.)

I have now treated all of the species of these insects known to attack cultivated grains in this country, though there may be still others as yet unknown. These known species have been described in each case, not especially for the benefit of the unentomological farmer, but because this publication will go to many lands and into the hands of many different peoples. Some will care nothing for descriptive matter, and such can easily pass over it in the use of this bulletin, but there will be others who will look to its pages for aid in determining with exactness the identity of the species which they may have before them, and for these descriptions are a necessity. Some of the species included may appear to be of no especial interest to the practical farmer, but of this no one can confidently predict. It may be true to-day and not true to-morrow, for no one can tell what year or in what part of the country any one of these, even the one that seems the most insignificant, may suddenly come to the front and commit serious depredations over a considerable area. Besides this, they are all of them so obscure in appearance and their effect on the plants they attack so subtile and hidden from the eyes of the farmer that he is unaware of his loss until on threshing his grain he finds that it does not turn out well and the kernels are light and shriveled. It is like the thefts of a trusted official—they are not missed until, by accident, perhaps, the defalcations are discovered, when we are struck with amazement at their magnitude and ask ourselves and each other how it is possible for such things to go on continually through a long series of years and escape detection. The financial loss occasioned by an unusually disastrous outbreak of these pests can be estimated, but it is a mistake to suppose that such losses constitute more than a very small percentage of the amount annually filched from the farmers by these insidious foes of his crops. It is not so much the big losses that occur at rare intervals, and of which we read much in the public press, but the infinite and perpetual leaks from this source that pull down the farmer's profits—leaks that, as has been shown, he may readily prevent in a most inexpensive manner. It is for the very reason of their obscurity and insidious attacks, coupled with the magnitude of the losses caused by them through a long series of years, that has prompted a study of their habits and the publication of the facts in the present form.

THE TWO-WINGED GRAIN AND GRASS FLIES.

The insects included under this head are true flies, having only two wings and their young are maggots without feet, eyes, or jaws. They belong to the family Oscinidæ, containing a large number of species with variable food habits, some of them not attacking plants, but living on the cast skins of other insects, shells of insect eggs, and in the burrows made in plants by other insects. Some of them are leaf-miners, others live in galls on grasses, while still others live underground on the roots of plants. Still others, that are known to live in the stems of grain and cause more or less destruction by their attacks, will be here considered, though it must not be supposed that there are not still others of such depredators of which we as yet know nothing.

Our grain-affecting species are to be found in the genera Meromyza, Chlorops, Elachiptera, and Oscinis. It is to the last that the very destructive frit-fly (*Oscinis frit*) of England and Europe belongs and which is so terribly destructive to grain crops in those countries. The habits of *Meromyza americana* have been pretty well studied and we now have a fairly good knowledge of its life history and habits; but of the most of the other species belonging to the above genera we only know that they attack the stems of wheat and other smaller grains, but we are far from possessing a full knowledge of their life cycles. *Chlorops proxima* Say is known to attack wheat plants in Kentucky, flies emerging in May; I have reared *Elachiptera longula* Loew from maggots in the stems of *Panicum crus-galli* in Illinois, the flies in this case appearing late in August, and from both wheat and oat plants in Indiana. It has also been reared from oats in Ohio by Prof. W. B. Alwood. From wheat plants in Indiana I have reared *Elachiptera nigricornis* Loew, and from the same lot of plants I reared also *E. costata* Loew, the latter having been reared from oats in Ohio by Professor Alwood and from maggots found in a decayed cavity in the roots of living garden radish in Illinois by Mr. Coquillett. The extent to which the larvæ of the last species attacks and destroys wheat plants is uncertain, for though I have reared them from volunteer wheat plants growing up in the fields I have never been able to separate their maggots from those of Oscinis. I have reared *Oscinis trigramma* Loew and *O. coxendix* Fitch from volunteer wheat plants in Indiana, and *O. dorsata* Loew, *O. coxendix* Fitch, *O. umbrosa* Loew, and *O. trigramma* Loew from August-sown wheat at Wooster, Ohio. *Oscinis carbonaria* Loew is treated in this paper under the head of the lesser wheat-stem maggot. The larvæ of all of these except Meromyza closely resemble each other, work in the young plants, and, some of them at least, destroy the central stem before the plant tillers or individual tillers afterwards. The larvæ or maggots are small, yellowish white, pointed anteriorly, but more blunt at posterior extremity, without jaws, but provided with a pair of minute hooks whereby they rend the tender growth of the plant and extract the juices. They may generally be found in the midst of their work surrounded by the injured tissue and grass saturated with the sap of the plant, and later on the brown puparia may be observed about the bases of the young plants in late fall and even outside the sheaths, and scattered on the ground in spring. They are often mistaken by farmers for the "flaxseed" or corresponding stage of the Hessian fly.

WERE PROBABLY ORIGINALLY GRASS FEEDERS.

Beyond a doubt the larvæ of these flies were originally grass feeding, and we find them at present developing in the stems of grass, but seemingly preferring grain at times, probably when the grain at the time of oviposition offers a more inviting place for the female to deposit her eggs with the assurance that her offspring will be within reach of an ample supply of food. Until the last half of the last century the average farmer paid little attention to such matters, and, as the flies were as now less thoroughly studied than other insects, there was little to encourage the entomologist in attempting to study their habits, as it is rather a thankless task to rear them and get their life history worked out only to learn that the species can not be determined, and the information thus gained is thus rendered practically worthless because of not being able to state definitely which of the many forms one has been studying. Only recently I have learned the name of a species reared from grass stems eighteen years ago. For this reason even now the earlier stages of nearly all of those reared from growing grain are obscure or unknown, the flies having simply been reared from grain or grass, but the young of any particular species can not be separated from those of perhaps a half dozen other similar flies. There is much need at present of careful studies of these insects with a view of determining their exact relation to agriculture, and especially to what extent they may be combated outside the grain fields of the farmer. At present not more than one farmer out of a thousand knows of their existence, and the injury they do is attributed to the Hessian fly, thus to a certain degree throwing obscurity over all reports of the ravages of the latter insect, which can not be reached outside the grain field, while some at least of these other flies surely can. When I began to study the life history of the lesser wheat-stem maggot, in 1884, it was the most unsatisfactory and, at that time, to all appearances, the most unprofitable piece of work that I ever undertook, for the reason that it was impossible to separate it from other similar species; but this has now been largely overcome with this insect, and we know that much can be done to prevent its injuries.

EARLY REPORTS OF INJURIES TO GRAIN.

One of the earliest reports of injuries to grain in this country that can be attributed to these insects with any degree of certainty was cited by A. S. Fuller, from the works of M. Du Hamel du Menceau (New Hamburg edition of 1759), as follows:

> There is a smaller kind of worm which gets into the roots, chiefly oats, and working upward destroys all the inside of the plant, which perishes soon after. I suspect it to have been an insect of this kind that destroyed so much wheat in the neighborhood of Geneva, and which M. de Chateauvieux described thus: "Our wheat in the month of May, 1755, sustained a loss which even that cultivated according to the new husbandry did not escape. We found in it many little white worms, which afterwards became a chestnut color. They post themselves between the blades and eat the stems. They are usually found between the first joint and the roots. Every stalk which they attacked grew no more, but became yellow and withered. The same misfortune happened to us in the year 1732. These insects appeared about the middle of May and made such havoc that the crop was almost destroyed."

The attack on oats was clearly that of the stalk borer or heart worm, the caterpillar of the moth *Papaipema* (*Gortyna*) *nitela* Guen., but that in the wheat does not accord with the work of any other than of some of these small grain and grass flies under consideration. Meromyza maggots do not turn brown or "chestnut colored," and those of the Hessian fly, even if it were known to occur in America at that early date, do not eat off the stems. As early as 1822 Mr. James Worth, of Bucks County, Pa., seems to have reared these flies from maggots attacking wheat.

It is therefore probable that as the area of cultivation increased in this country these insects have gradually transferred their attention from grass to grain as a matter of necessity, and though more or less numerous every year in the grain fields, they become excessively so when the grass conditions are less favorable than those of the grain; but the grasses are a continual source of supply from which the grain fields are colonized. These interrelations may be more or less curtailed by the farmer with but little expense.

THE GREATER WHEAT STEM-MAGGOT.

(*Meromyza americana* Fitch. Fig. 14.)

PAST HISTORY OF THE INSECT.

This is in all probability an insect native to the far South, as it occurs in Mexico and northward over the entire United States and far into British America, its food plants, before the advent of the Caucasian farmer, being the wild grasses. The fly was described in 1856 under the name here applied, but without definite proof of its attacking grain further than that it was collected in wheat fields and closely resembled the European species *Meromyza saltatrix* Linn. There is now, however, considerable evidence of its having attacked growing wheat at least as early as 1822 in Pennsylvania[a] and in 1845 in Michigan.[b] The evidence furnished by Mr. James Worth, of Bucks County, Pa., indicates that three broods were observed, as he calls attention to the attacks of "a little worm found in the lower part of the stalks of wheat and rye in spring and fall and about the joints in June." Of these larvæ he says that "some were pale yellow, with brown spots about the mouth," which would imply that they were those of some species of Isosoma; but he further states that one kind was found in volunteer wheat, which the Isosomas do not attack, and their larvæ are not found in the plants in fall, and in case of only one, with a possibility of another species, are they to be found in the plants in spring. While Mr. Worth evidently was not able to separate the different species of the larvæ found in growing grain, his careful descriptions and exactness in locality and dates are exceedingly valuable and enable those familiar with the forms of which he writes to recognize them with reasonable clearness. Hence we are left with little doubt that he observed the larvæ of Isosoma and Meromyza

[a] The American Farmer, vol. 4, p. 394; Memoirs Penn. Agl. Soc., Vol. 1, p. 165.
[b] Prairie Farmer, Sept., 1845, p. 216.

without separating them, and also in fall, including those found in volunteer wheat, this latter species and other Oscinidæ. The reference in the Prairie Farmer seems to have been drawn out by a notice in the Michigan Farmer of a new wheat insect in that State, described as the product of a greenish fly about three-sixteenths of an inch in length, whose larva is a white worm one-fourth of an inch long, ribbed, without feet, with two forked lines on its forehead, found in the straw above the upper joint, where it devours the juices which would otherwise ascend to the head, but which denote the presence of the worm in the straw by turning white prematurely when the grain is in the milk. There is also here reference to the presence of "9 eggs * * * found in a single straw, one of which had just hatched," but which eggs, so called, are now known to have been the bodies of a minute parasitic mite, whose rounded form is not unlike that of an egg and which is occasionally found attacking the maggot in the straws.

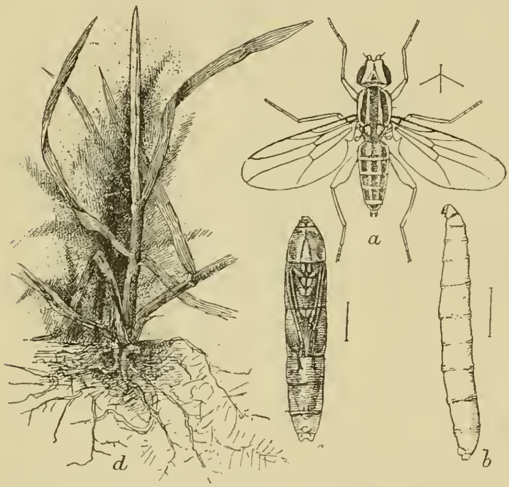

FIG. 14.—Greater wheat stem-maggot (*Meromyza americana*): *a*, mature fly; *b*, larva; *c*, puparium; *d*, infested wheat stem—all enlarged except *d* (from Marlatt).

Doctor Fitch did not rear the flies which he described, but collected this in connection with several species of Oscinis by sweeping in the wheat fields with an insect net. Being familiar with the grain attacking habits of similar insects in Europe, he expected, as he says, to rear the flies from the growing wheat plants at different seasons, but failing, as he states, to do this, contented himself with describing the flies without attempting to connect them with the injuries which he clearly observed. Nothing further appears to have transpired relative to this insect until in the year 1867, when Doctor Riley reared the fly from larvæ working in the growing stems of wheat, immediately above the upper joint, in the month of June, and in Missouri. In this case the flies appeared during the first week of July, after a pupal period of twelve to fourteen days. These facts were published in the Rural New Yorker for January 28, 1869, and in his first report as State entomologist of Missouri he discussed the insect and gave illustrations of the adult, larval, and pupal stages, but does not appear to have suspected the occurrence of a second brood later in the season. In 1876 a farmer of Hinckley, Ohio, reported it as attacking his spring wheat.[a] We

[a] Country Gentleman, July 27, 1879.

also hear of it during this same year in the State of New York, where stalks of growing wheat containing the larvæ were sent to Doctor Lintner, from Scipioville, in August. Some of these stalks contained larvæ, and some of the flies were observed crawling about on the table where the package had been unwrapped, and these were supposed to have emerged from the straws while in transit. Doctor Lintner adds nothing to our knowledge of the species at this time, but gave it the common name of the wheat stem-maggot in preference to Doctor Fitch's American Meromyza.[a]

In March, 1883, Dr. S. A. Forbes, State entomologist of Illinois, received information of serious injuries to young wheat in Fulton County, of that State, and on investigation found the depredator to be a small, slender maggot which attacked the plant just above the root, thereby killing it. Farmers in the infested territory had noticed the injury during the preceding November and December, but had not taken steps to learn of its destructive character until, with the coming of spring, the pest seemed to break out anew. From larvæ taken from infested plants from these fields puparia were obtained April 30, and the flies began to appear by May 4, and continued to emerge until June 1, thus showing that the insect might do serious damage to young wheat in the fall, pass the winter in the maggot stage, and resume its work of destruction again in spring. This, taken in connection with what had been observed by Riley and Lintner, showed plainly that the flies emerging in May and June oviposited in the growing stems of the wheat, and the larvæ hatching from these eggs entered the stems just above the upper joint. Doctor Forbes, in his thirteenth report as State entomologist, gave full details of his observations and called attention to the possibility of a third brood developing in midsummer, and also gave the insect the common name of the "wheat-bulb worm."[b]

During the summer of 1884 I was engaged as a special agent of the Division of Entomology, under Doctor Riley, and from June 1 to October was located at Oxford, Ind., engaged in the study of grain insects, especially those attacking wheat. From straws taken from a field near Oxford I reared adult flies up to July 26, and volunteer wheat, taken from this same field September 5 and sent to Washington, gave adults September 11, 13, and 16, according to the divisional notes. During the same year adults were reared from volunteer wheat October 1 and found in the field of young wheat on October 6.[c] In 1886 Doctor Forbes put the final touch, so to speak, to the settlement of the occurrence of this midsummer brood by finding both eggs and larvæ on August 4 in volunteer wheat, and in his fifteenth report (p. 39) constructed a calendar showing the periods covered by the several broods.

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[a] Loc. cit., Vol. XLIV, p. 535, 1879.

[b] 13th Rept. State Entomologist of Illinois, pp. 13–29, 1884.

[c] Rept. U. S. Comm. Agr., 1884, p. 390; Bull. 9, Purdue Univ., Oct., 1886.

This calendar shows our combined work on the insect, and is all the more valuable on account of our having worked entirely independently of each other over territory within the same latitude, and with other conditions in every way similar. It is also a matter of interest that on February 27, 1891, I collected all stages of the insect except the eggs in wheat growing on the grounds of the Agricultural College of Texas, at College Station.

LIFE HISTORY.

Throughout the region of latitude 40° N. the insect is three-brooded, although there may be but two in the north and more than three in the far south, though Doctor Fletcher states that about Ottawa, Canada, about latitude 45° N., there are three broods, the adults appearing in the beginning of June, the end of July, and again late in September. My observation in Texas, about latitude 30° 30′, does not necessarily indicate additional broods, as there may be, as with the Hessian fly, a prolonged summer resting period, during which the insect is continued in a stage requiring no food and incapable of reproduction, until the vegetation upon which the larvæ are dependent for their food supply begins to take on new life, and, as with the Hessian fly, we may find that the very conditions that serve to prevent the starting up of the fresh growth of vegetation, so essential to the life of the young larvæ, has also the effect of retarding the emerging of the parent insects. Such problems as these are for National investigation, where imaginary lines and political boundaries do not enter into consideration. Within the wheat belt of the United States, broadly speaking, the life cycle of this insect is as follows: The winter is passed in the larval stage, and the short pupal stage coming in May brings the emerging of the adults at the time when the female is able to place her eggs on the plants where the young, on hatching, will make their way to the tender and succulent stem just above the upper joint. By the time the straw has ripened the larvæ have ceased to require food, and pass through the pupal stage, the adults of this brood appearing in July. Eggs are now deposited in volunteer wheat and grass, and, owing either to the retarding effects of meteorological influences or a diversity of food of the larvæ or both, perhaps, the emerging of the adults is prolonged throughout a period extending from late August through September until late October. At this period the fall wheat offers a decidedly inviting plant to the female fly on which to place her eggs with a prospect of her progeny having an abundant food supply. It is the larvæ from eggs deposited during this period that winter over in the plants and give rise to the May-June generation of flies. It is this last brood that is of more especial interest to the farmer, as it is very seldom that the pest does serious injury to grain except in fall and early spring.

DESCRIPTION.

Adult.—Length, 0.17 inch to tip of abdomen and 0.20 inch to end of wings. Color, yellowish white, with a black spot on the top of the head, which is continued backward to the pedicel of the neck. Thorax with three black stripes, approaching each other anteriorly, but not coming in contact, the middle stripe prolonged anteriorly to the pedicel of the neck and posteriorly to the apex of the scutel. Abdomen with three broad, blackish stripes, which are confluent posteriorly and interrupted at each of the sutures. Tips of the feet and veins of the hyaline wings blackish. Eyes, bright green. Antennæ, dusky on their upper side. (Lintner.)

Egg.—Snow white, fusiform, longitudinally ridged, the space between the ridges being concave and marked off into rectangular areas by still slighter ridges transverse to the others. Length, 0.023 inch; breadth, 0.005 inch. (Forbes.)

Larva.—Very pale green, slender, footless, tapering anteriorly, somewhat narrowed, but subtruncate posteriorly; one-fourth of an inch in length by about one-eighth of an inch in width. The segments are thirteen in number, including the head, those in the center of the body being a little wider than long. The four anterior segments narrow rapidly forward, the one next the head being at its apex less than half the diameter of the fourth. The three posterior segments are also somewhat narrowed, the penultimate being about three-fourths the diameter of the second preceding. The head is provided beneath with the pair of black toothed hooks common to many dipterous maggots. The antennæ are very short, scarcely longer than broad, two-jointed, the second joint extensile. There are two circular, apparently sensory, areas below the antennæ upon the front of the head, doubtless representing maxillary palpi. The mouth is beneath the head, sucker-like in form. The last or anal segment is divided into two lobes and bears upon its posterior surface two breathing pores or spiracles, each guarded by a circlet of about twelve depressed spines. The surface of the larva is entirely smooth and shining, except for some very fine transverse ridges on the under side of the segments, evidently used in locomotion. On each side of the base of the second segment is a small, gill-like appendage, divided into two lobes, each lobe with six divisions. (Forbes.)

Pupa.—The pupa of this species is what is technically known as a coarctate pupa, contained within the last skin of the larva, which is not shed previous to transformation, but remains as a protective envelope for the forming pupa. As the latter shows through its case, the color is green, except at the ends, where, with the growth of the pupa within, the case is left empty and transparent. It is about one-sixth of an inch long by one-fifth in width, and divided into ten clearly recognizable segments. The anterior of these, corresponding to the head and first segment of the larva, is yellowish, shrunken, and corrugated, about half the width of the third segment. The second and third are obscurely divided, the first being short and narrowing rapidly forward. Within it are observed the retracted maxillæ of the old larva. The remaining segments to the eighth are about equal in length, separated by deeply impressed sutures at first, the anterior sutures becoming obliterated as the enlargement of the head and thorax of the pupa within distends the envelope. The ninth segment is the longest of all, the tenth being nearly equally long, but narrower, and shrunken and wrinkled on its posterior border. The eleventh, representing the twelfth of the larva, is only a brown and corrugated rudiment. As the development of the pupa approaches completion, the eyes, wing-pads, and legs are visible through the transparent covering, but they form no elevations of the surface. (Forbes.)

FOOD PLANTS.

Besides wheat, rye, oats, and barley, all of which it has long been known to infest, I have reared *Meromyza americana* from the common bluegrass (*Poa pratensis*), while Doctor Fletcher, in Canada, has reared the flies from maggots in the stems of Agropyron, Deschampsia, Elymus, and Poa, and as he states that the flies are enormously abundant in meadows and prairies all the way from northern Quebec through the Lake Superior region, Manitoba, and the Northwest Territories, there seems to be ample proof of its ability to sustain itself without trouble among the grasses of that country.

The extent to which it attacks fall wheat in autumn is entirely obscured from the fact that, in the majority of cases, it is confused in its work of destruction with the Hessian fly. In Ohio, at a time when the Hessian fly was being accused of devastating whole fields of wheat in the fall, by collecting a great number of the affected plants at the beginning of winter and placing them in the insectary I reared fully as many of these as I did of the Hessian fly, which at that time I was especially engaged in investigating. It is on this account that the entomologist who attempts to study the economics of the Hessian fly, which does not breed in the grasses, will find the greatest difficulty in weighing the evidence offered by those who can not or will not note the difference in the nature of these insects and the great similarity in the final effects of their attacks upon growing fall wheat in autumn and spring.

SELECTION OF FOOD PLANTS BY THE ADULTS.

Either some varieties of the same kind of grain are more or less repugnant to the flies, or else they possess a very finely adjusted sense of the larval preferences for certain other varieties, for they certainly exhibit a considerable discrimination in their selection of the different varieties of wheat on which to place their eggs. Doctor Forbes has called attention to the fact that the most seriously injured fields of wheat in Fulton County, Ill., in 1883, were of the Fultz variety. At Lafayette, Ind., June 14, 1889, among a lot of experiment plats on the experiment-station grounds, sown side by side, on the same day, with the same soil and other conditions, there was a marked difference between the number of affected straws in the Velvet Chaff and in the Michigan Amber, the infestation being fully four times greater in the former than in the latter. Even in the case of larger fields bordering each other the conditions did not vary, and where the two varieties overlapped along the margins the same partiality for the Velvet Chaff had been shown. Doctor Fletcher has also noted a strong prejudice in favor of some varieties of the same kinds of grasses. For instance, while *Poa serotina* was one of the most seriously affected of all of the grasses, *P. pratensis*, *P. cæsia*, and *P. compressa* were almost exempt from attack. Attack on *Setaria viridis* was observed in a single instance.

PLACE AND METHOD OF OVIPOSITION.

According to Forbes, the eggs are placed on the stems of grain, "some being pushed down beneath the ensheathing bases of the leaves and others cemented to the stems just at the margin of the sheath, while still others were placed along the edge of the sheathing base of the leaf, sometimes being thrust under the edge." This agrees with my own observations and is doubtless the usual method of oviposition, as the main object on the part of the female is to place the eggs where the young larvæ will the most easily reach the tender, juicy stem as soon as possible after escaping from the egg, and is probably true in the case of grasses as well as of grain.

METHOD AND NATURE OF ATTACK.

Both Doctor Lintner and Doctor Forbes have endeavored to indicate this by the selection of explanatory common names for this insect. The former, disregarding Fitch's name, American Meromyza, as too technical, and having observed the larvæ in the full-grown straws only, gave it the name of the "wheat-stem maggot," while Doctor Forbes, having first encountered the larvæ in the bulbous lower stem in early spring, gave it the name of the "wheat-bulb worm," on account of its resemblance to the "wheat-bulb maggot" (*Hylemyia coarctata*) of England. It is really a maggot and affects the stems of the plants which it infests, besides being the largest maggot of this kind at present known to attack the stems of grain in this manner in this country; hence, in order to distinguish it from other smaller stem maggots, I have here termed it the "larger wheat stem-maggot."

The larva has no jaws or mouth, but a couple of hook-shaped appendages by which it tears the plant and feeds from the juices, the cavity made by this destruction of the stem being filled by a pomace-like mass in which the larva is to be found. The effect on the plant is shown by the accompanying illustration (fig. 14, *d*). In young plants the central spindle-shaped enfolded leaf is killed, precisely as with attacks of Oscinis larvæ, the detached portion turning first yellow and later brown, then shriveling up and dying, leaving the outer lower leaves uninjured. In Hessian-fly attacks this spindle-shaped leaf is absorbed and does not appear at all in young wheat in autumn, so that there need never be any confusion of the work of these two insects in fall wheat, and the effect on the full-grown straws is even more easily distinguishable. When attacked by the maggots of this species the fully grown straw withers at the upper joint and all that portion of the stem including the head, the sheath excepted, changes to a whitish color, the remainder of the plant, including the upper sheath, continuing uninjured and of the usual green color. The Hessian fly never affects the full-grown straws in this manner and the lesser wheat stem-maggot does so but rarely, so that the presence of these maggots in the straw can be easily detected shortly prior to harvest by their whitened color from the upper joint upward. The larvæ are within the stem and not outside and under the sheath, as with the Hessian fly; they are larger and of a more glassy green color than those of the lesser wheat stem-maggot, and it is only when still very young that the ordinary farmer need ever mistake them for any of the others mentioned in this bulletin. It is only in the manner of killing the stem of young wheat that it need be confused with others.

EXTENT OF RAVAGES.

Though present in the fields every year, as is witnessed by the whitened heads of grain in the fields just prior to harvest, I have never known a serious attack at that season of the year; nor is there anything at present to indicate that it is likely to work more serious injury at this season in the future than it has in the past.

Its ravages in the young wheat in fall and spring, as illustrated by the outbreak in Illinois in 1882–83, are not as yet of usual occurrence, though several similar instances have come to my knowledge within the last twenty years. In two cases—one in Indiana in 1888 and another in Ohio in 1900—the fields were also badly infested by Hessian fly, but from the material reared it would seem that this species was to be credited with no small percentage of the loss. Occasionally fields of fall wheat, especially if sown early, are attacked in the fall and ruined by this insect alone, though the damage is in some cases attributed to the Hessian fly. It is, however, easy enough to detect the difference between injuries caused by these insects, as has been explained under methods of attack.

PREVENTIVE MEASURES.

The liability of attack from this insect is not sufficiently great to warrant any expensive measures being put forth in order to forestall possible outbreaks. As yet, we have no way of foretelling these sudden attacks, as the pest has never proven excessively abundant in the same locality two years in succession. The fact that late-sown wheat is less subject to injury, and in cases where the two have been found in a combined attack, the grain has been sown early, indicates that this now-accepted method of warding off an attack of Hessian fly will work equally well with this species. There is nothing at present to indicate any change from these conditions throughout the winter-wheat growing regions of the Northern States. Whether or not the same rule will apply in the South remains to be seen, as we know too little of the pest in that portion of the country to be able to speak positively. In the North, in the regions devoted to the raising of spring wheat, it would appear that a burning over of the grass lands in winter would reduce the probabilities of attack. The destruction of volunteer wheat, which should be done in any case as a protective measure against attacks of Hessian fly, will of course tend to reduce the probability of the young wheat being attacked in autumn. It must be borne in mind, however, that this is a grass as well as a grain insect, and eradication from the grain fields will not protect from infestation from without.

NATURAL ENEMIES.

The abundance of one of these and the extent to which they are able to perform their deadly work is a most encouraging feature, viewed from the standpoint of the husbandman. A small, shining black, four-winged fly, with reddish-yellow legs (*Cœlinius meromyzæ* Forbes), is exceeding beneficial in its parasitic work on the maggots of this pest. This parasite was discovered and described by Doctor Forbes in connection with the investigations of the outbreak in Illinois in 1883. So abundant is this parasite that it is almost impossible to rear the flies from the straws in July without also rearing numbers of these diminutive friends. They attack the maggots by placing their eggs in their bodies, and the eggs hatching feed upon the maggots and destroy them. This parasite occurs generally with the depredator, even in the far North.

Another natural enemy is the mite *Pediculoides* (*Heteropus*) *ventricosus* Newport, illustrated on page 22. The young of this insect are so very minute as to be quite invisible to the unaided eye. They are without wings, but very active, and make their way to the maggot working within the stem and fastening themselves upon it suck its blood, in the meantime themselves increasing rapidly in size until they appear like minute globular eggs, the abdomen being distended with young, as there are no males, and the body having much the proportions the stem has to the pumpkin. Each female gives birth to a great number of young, which at once either escape to other stems to hunt out their victims or else settle down with the parent. These are frequently found attacking the maggots and are apt to escape detection, or, if observed, mistaken for eggs. The reference in the Prairie Farmer, calling attention to the presence of what probably were these maggots in stems of wheat previously cited, also mentioned the presence of nine eggs with the maggot. Without a doubt these were the mites that had attacked the maggot, though this was long before the mite was known to inhabit this country, it being a native of Europe, as far as now known.

THE LESSER WHEAT STEM-MAGGOT.

(*Oscinis carbonaria* Loew. Fig. 15, *d.*)

With our present knowledge of the early stages of development it is yet impossible for me to separate out from several other allied species such as belong to this one and give a detailed account of its life cycle, and especially is this true with reference to *Oscinis soror*, or what is the same thing, *Oscinis variabilis* Loew. To be able to do this will require the most careful and exact studies of the early stages of the offspring of adult flies belonging to each species ovipositing on plants known of a certainty to be free from infestation by other species. Such studies can only be carried out with the aid of better conveniences than I have had at my disposal, and should be taken up by the General Government, whose investigators are not restricted by State lines, and who can follow wherever their problems may lead them.

Though *Oscinis soror* (*O. variabilis*) has been reared from growing wheat by others as well as myself, I have found that *O. carbonaria* has been thus obtained with the greatest frequency over the widest range and under conditions that lead to the belief that it is the more important of the two, from an economic point of view at least.

LIFE HISTORY.

This can only be given in a general way, as in no instance has the progeny of a single female been carried through the life cycle and the several broods throughout the year clearly defined. I have myself reared this species from growing wheat in Illinois, Indiana, and Ohio, over not to exceed two degrees of latitude, or collected them in the wheat fields throughout this area, or they have been reared in Washington in the Department insectary from plants sent there by me from this same territory, as follows: Urbana, Ill., July, August, and September; Oxford, Ind., from May to October, not inclusive; Lafayette, Ind., July, August, and September; Wooster, Ohio, May, June, July, August, and September; and in the latter locality from August-sown wheat. In the insectary I have also reared it in November, December, and the following April, but did not observe it abroad in that locality during November, December, or April. Besides these rearings of mine, it was reared at Washington, July 7, from plants received on the 3d of same month from Prof. Lawrence Bruner, West Point, Nebr., and reared by Forbes, in Illinois, September 17, from volunteer wheat. This is the species mentioned by Doctor Fletcher as being so destructive in the Dominion of Canada in 1890, as shown by specimens of the adult which he has kindly sent me.[a]

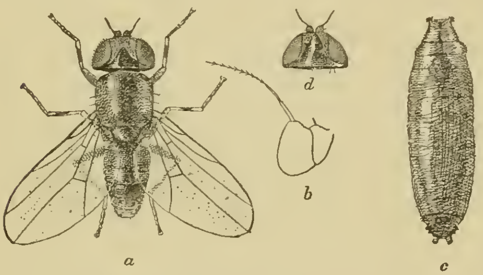

FIG. 15.—*Oscinis soror* Macq.: *a*, mature fly; *b*, antenna of same; *c*, puparium; *d*, head of *O. carbonaria*—*a*, *c*, *d*, magnified; *b*, still more enlarged (original).

There was a bad outbreak of this insect in a field of wheat near Wooster, Ohio, in the fall of 1891, and the field was badly affected. In March of the following year I found many larvæ and pupæ about the bases of the affected plants, and an attempt was made to study

[a] See Experimental Farm Reports, 1890, p. 158, and 1898, p. 177.

them further, but insufficient facilities for doing so prevented. There was, however, plenty of evidence that the insect may winter in either the larval or pupal stages. A single specimen was reared at the Department in Washington from a stalk of wheat received from Mr. J. G. Kingsbury, editor of the Indiana Farmer, the fly appearing June 18. In this case the maggot was in the straw above the upper joint, and the wheat head was evidently killed by its attack. From all of these facts it seems that its life cycle may be about as follows: It may winter over in the field either in the larval or pupal stage, the adults emerging in May. From the presence of larvæ in the stems of wheat and grass from which adults have afterwards been reared it would appear that there is a brood of flies emerging in June and July, much as in *Meromyza americana*, which lay their eggs in grass and volunteer grain; another brood of flies resulting in September and October whose offspring hibernate as previously stated, there being, as in Meromyza, three broods each year, from six weeks to two months being required for the insect to pass through its development during the summer months.

FOOD PLANTS.

I have reared these flies only from wheat, probably because I have made no special effort to rear them from any other plant. Doctor Fletcher has reared the species from *Agropyron caninum*, *A. tenerum*, *A. repens*, *Poa pratensis*, and *Elymus canadensis*.[a]

PLACE AND METHOD OF OVIPOSITION.

I have observed oviposition only among small wheat plants, but presume that the methods employed in such cases do not differ from those where the food plant is some of the grasses. The object on the part of the female seems to be to place her eggs low down on the plant, as near the root as possible and along the enveloping edge of the sheath. The very young larvæ are always to be found in this situation, and the edges of the enveloping bases of the leaves are always ragged and discolored in infested plants.

NATURE OF THE INJURY.

The young maggot on hatching from the egg feeds along the thin edge of the lower base of the enfolding leaf where it is white, juicy, and tender. It seems to make no effort at first to reach the central portion of the plant, seeming to know that that part will remain tender and succulent, but gradually works its way inward and upward to a point just below where the central spindle-shaped unfolding leaf leaves the ensheathing portion of the next older one, the exact locality seeming to be decided upon according to the toughness of this central

[a] Experimental Farms Reports, 1890, p. 158.

leaf, which of course varies with age and may be the first slender shoot of the plant, or one of the older and tougher tillers of much older plants. This central compactly rolled leaf is cut off, the maggot at first working upward until this leaf becomes too tough or begins to wither, when it reverses its position and works downward, where the food supply is always fresh and juicy. Pupation does not take place here, but the larva makes its way when full fed to between the bases of the older leaves, and in that situation the puparia are to be found. A very young plant does not admit of very extended travel by the larva, and in an older one the continuity of its path is soon obliterated by the growth of the plant itself, and the larva is frequently found a couple of inches above the base where it entered after hatching from the egg, as is witnessed by the minute patches eaten out of the leaf. As but a single maggot is found in each stem, I have often wondered if the female so distributed her eggs as to prevent a clashing of young, and feel very much inclined to the opinion expressed in some unpublished notes by Mr. Pergande to the effect that more than one egg may be deposited about a single stem, but the oldest and strongest maggot kills off the weaker, leaving but one in full possession.

EXTENT OF RAVAGES.

Usually the work of this species is so confused with that of others as to render anything like a definite estimate of the damage that can be justly charged to its attacks in the grain fields almost impossible. I have never observed injuries to the full-grown straw, though I have occasionally found larvæ in them that I presumed to belong to this species. In fall wheat the plant recovers from a slight injury, especially if growing in a fertile soil, and I apprehend that more damage will follow an attack in fields where the soil is poor or badly worn than where it is richer. In the field of wheat near Wooster, Ohio, that was so severely injured in 1891, the Hessian fly was also present and did fully as much injury as this insect, both I should say, destroying fully one-half the crop. Dr. Fletcher has called attention to a field of spring wheat in Canada that was damaged fully 75 per cent, for the most part due to the attacks of this species. In the United States, I do not believe that an injury of from 5 to 15 per cent of the crop by reason of the attacks of this and other Oscinis is at all unusual, but this can not in all cases be wholly charged up to this particular species.

DESCRIPTION.

The following description of the fly of *Oscinis carbonaria* has been kindly drawn up for me by Mr. Coquillet:

A small, black, two-winged fly having the knobs of the halteres, the feet, and usually both ends of the tibiæ yellow. Length varying from 1 to nearly 2 millimeters (from one twenty-fifth to nearly one-twelfth of an inch). The last joint of the antennæ is nearly circular in outline, and on the upper edge is a nearly bare bristle or arista; on the upper part of the otherwise opaque head is a polished, nearly triangular spot that extends from the extreme vertex almost to the antennæ. The wings are nearly transparent and are without an auxiliary vein—that is, there are only three (instead of four) veins that terminate in the front edge of the wing before its apex; the vein bordering the front edge of the wing extends beyond the extreme apex of the wing; the usual two small cells near the base of the wing are wanting, the anterior one being confluent with the discal or central cell, while the posterior one is wanting, there being only one cell (the axillary) behind the fifth vein. The legs are devoid of bristles and of stout, apical spurs, and are rather short and robust; the first joint of the feet is rather slender and longer than any of the other joints. The thorax is also without bristles, except along the sides and across the posterior end; it is somewhat polished and is devoid of gray dust. The face does not project strongly forward on its lower part; the proboscis is short, robust, and terminates in the fleshy lips.

CLOSE RESEMBLANCE TO OSCINIS SOROR MACQ.

Oscinis soror Macq. is very closely related, but may be distinguished by the fact that the polished spot on the upper part of the head extends only about halfway from the vertex to the antennæ, instead of almost reaching the antennæ, as in the preceding species. (D. W. Coquillett.)

At present, owing to the confusion of this species with *soror*, an account of which will follow, it seems impossible to give desirable descriptions of the preparatory stages of this insect. I have followed those of Professor Garman, not knowing whether he was dealing with this species or not, but because his descriptions seem to me to apply as well to this as any that I could supply. It must be kept in mind, however, that this is only a temporary makeshift to give some kind of an idea of what these look like, and thus enable the farmer to reduce the uncertainty as to the identical species that is injuring his crop, and that later and more careful investigations will probably show that this and several other species, but with habits that are practically the same, have been confused, and thus the present arrangement serve a practical if not a scientific purpose.

Egg.—The egg of what is supposed to be this species was described by Mr. Pergande in the Department notes as follows: Colorless, polished, and longitudinally ribbed with numerous extremely fine transverse striæ.

Larva.—Cylindrical, white, with faint yellow cast. Body composed of thirteen segments. No head and no legs. Mouth with two strong black hooks. Posterior segment of body with a pair of knob-like prominences. Length of alcoholic specimens, 0.14 inch.

Pupa.—In this stage the insect is inclosed in the hardened and brown skin of the larva and this is called the puparium. This last is bright yellowish-brown, with distinct and very finely wrinkled divisions. The two knob-like prominences in the larva are retained and are conspicuous at one extremity. The black hooks of the larva are molted with the skin and can be seen through the puparium. The obsolete mouth of the larva is withdrawn, blackened, and wrinkled. Length from 0.10 to 0.14 inch.

PREVENTIVE MEASURES.

It is doubtful if one farmer out of a thousand fully realizes the danger arising from volunteer wheat. This growth springs up in the fields in greater or less abundance, and is almost invariably left to itself, as, having no value, it is thought not worth while to bother with it. Besides, the general practice in many sections of the country of seeding the wheat lands to timothy and clover would prevent any attempt to destroy the volunteer wheat, except by pasturing, which is not considered a part of good husbandry at that season. A rotation of crop, however, has in itself some advantages, as it forces the flies to migrate from one field to another, in which there must be more or less casualties, and many more would probably be attracted to the grasses and the young fall wheat be protected to this extent from attack. Where wheat is to follow wheat in the same field, it will certainly pay the farmer to destroy this volunteer growth, as it not only harbors all of these flies and offers unusual advantages for the development of this midsummer brood, but it offers a breeding place for the Hessian fly as well. Volunteer wheat, then, should be destroyed wherever possible by the plow or disk harrow, and, where practicable, by pasturing, so as to prevent the flies from breeding therein. Burning over the grass lands, except timothy or clover, where it is probably not necessary, will offer much protection, especially in spring-wheat growing regions, and where fall wheat is much grown, reasonably late sowing will probably prove one of the most effective means of protection.

NATURAL ENEMIES.

While this species probably has its usual number of natural enemies, it is not always possible to determine the exact species from which these have been reared, but an insect that is parasitic on one species of these flies might be confidently looked for as being parasitic upon other allied species. *Rhyssalus oscinidis* Ashm. is parasitic on a species of Oscinis larvæ mining in the leaves of plantain, in Washington, D. C. *Aphæreta californica* Ashm. and *A. oscinidis* Ashm. have both been reared from other species of Oscinis, while I have reared *Cyrtogaster occidentalis* Ashm. from either this species, *O. soror*, or *O. umbrosa*, in Indiana, though it is known to occur from Texas to South Dakota and east to Virginia and the District of Columbia. These are all minute four-winged flies, and there are probably many others that also help to keep these flies reduced in numbers. I have also observed the common parasitic fungus *Entomophthora muscæ* attacking the flies, but this is probably a minor factor among their natural enemies.

THE AMERICAN FRIT-FLY.

(*Oscinis soror* Macq. Fig. 15, p. 52.)

This species has been so interminably confused with other allied species, especially with what has been going the rounds as *Oscinis varabilis* Loew? a synonym, and as frequently confused with *O. carbonaria* as with this, that it seems almost impossible to say anything about it with any degree of certainty that one is not really dealing with something else. *Oscinis soror* is, nevertheless, a valid species, and its larvæ in all probability attack growing grain, though I have myself rarely reared it from grain, and my proof of its destructiveness in wheat fields is unfortunately not as conclusive as I wish it were. The larvæ certainly have a wide range of food plants, as I have reared it from maggots in the stems of *Panicum crus-galli* in Indiana during September, and also from the stems of *Poa pratensis* in June and from wheat in July. It has also been reared from larvæ wintering in the seed capsules of *Vernonia noreboracensis* May 15 in Washington, D. C.; in June and July, at Columbus, Ohio, from oat plants; from the roots of cucumber, October 2, in Maryland; and from strawberry plants in Michigan. Last year I reared the flies from the stems of *Eragrostis minor* at Urbana, Ill., in September. These definitely authenticated rearings of the flies show a wide range of food plants, and the species is one of the most abundant of all the Oscinids.

CONFUSION WITH OTHER SPECIES.

Owing to a species having been found in Illinois and Kentucky attacking wheat and doubtfully determined by Doctor Williston as *Oscinis variabilis* Loew, now known to be a synonym of this species, and this determination having been applied elsewhere to other Oscinidæ attacking wheat, has led to much confusion, as where the name *O. variabilis* has been applied to a form committing depredations, we can not say with any degree of certainty whether the insect involved was this species or *O. carbonaria*, unless specimens actually reared from the plants so attacked are at hand. Realizing the difficulty when I began the preparation of this bulletin, I applied to Mr. Coquillett, of the United States National Museum, for suggestions as how to best overcome it and received from him an offer to determine any material reared from larvæ attacking wheat in various parts of the country. Doctor Fletcher had published accounts of the ravages of *Oscinis variabilis* Loew? in Canada, Dr. Otto Lugger of similar ravages of *Oscinis soror* in Minnesota, and Professor Garman of the attacks of *Oscinis variabilis* Loew? in Kentucky. Application was therefore made to Doctor Fletcher, Professor Washburn, successor tô the late Doctor Lugger in Minnesota, and Professor Garman, for reared material in order to as far as possible place the responsibility for these depredations on the species actually engaged therein. Material kindly placed at my disposal by Doctor Fletcher has shown that it was *Oscinis carbonaria* Loew that committed the depredations in Canada. Professor Washburn was less fortunate, though he did all that was possible for him to do to aid me, and sent specimens that, judging from the labels attached, had been reared by Doctor Lugger, but whether from wheat or not it is impossible to determine, as nothing could be found that would throw any light upon this point. The specimens sent me from Minnesota by Professor Washburn comprised two species, *O. soror* and *O. dorsata* Loew, the former having been supposed by Doctor Lugger to have been responsible for the injuries to wheat in Minnesota in 1892, while the latter was reared by me from wheat plants in Ohio in the fall of 1897, thus indicating that both might have been involved in the Minnesota trouble. Assuming that Doctor Lugger had sufficient grounds for holding *Oscinis soror* responsible for the damage in his State at the time stated, I have so considered it here, but have thought proper to indicate the uncertainties surrounding this conclusion. Not being able to secure any material whatever from Professor Garman, I am forced to reluctantly place the blame for the outbreak in the wheat fields in Kentucky in 1889 upon *Oscinis soror*, but with a strong suspicion that it was really *Oscinis carbonaria* that was responsible for the trouble. I have applied Doctor Lugger's descriptions of the larva and pupa to this species as being the best that can be done with our present knowledge of these insects, but subject to revision, as future investigations shall clear up more or less of the obscurity at present surrounding them.

DEPREDATIONS IN MINNESOTA.

There is one fact connected with the Oscinis problem in Minnesota that seems to point especially to *O. soror* as the real depredator, and not *O. dorsata*, and that is in the striking difference in the color of the two, the former being black and the latter yellow, a difference that could hardly have escaped the keen eyes of Doctor Lugger, and I can not but feel that he was correct in his attributing the depredations to the species now being considered. I strongly suspect that some of the "deadheads" to which Doctor Fletcher has called attention in his reports and other publications as occurring in the wheat fields of Manitoba and the Northwest Territories may have been to some extent due to the work of this species also.

Doctor Lugger seems not to have studied the several generations of the species in his State (Minnesota), but gave his attention especially to the one that proved the most destructive. From what has been stated of the insect farther to the southward, it would appear that there are the same number of broods as with *O. carbonaria*, the pest wintering over in the young plants of fall wheat and grass. In Minnesota it evidently winters in the straw, from which it would seem that in the north there is one less brood than there is farther to the south, a condition of affairs entirely possible, as we now know that the Hessian fly is there largely at least single brooded, but double brooded farther south. In his second annual report as State entomologist, pages 6 to 10, Doctor Lugger gives these facts relative to the work of the insect in his State:

During the summer and early part of the fall numerous letters were received from many parts of the State in which the writers complained about minute worms which infested the stems of wheat just above a joint from 3 to 4 inches above the ground. The specimens received at the same time showed that, as a general rule, the first and second joints of the plant were infested. Some farmers complained that their crop of wheat was thus very materially reduced. The plants harboring the worms did not indicate their presence until flowering time, but as soon as the head began to form the stem above the injured joint wilted, turned yellowish, and soon broke down entirely by bending over the infested spot. * * * But when the infested stems were investigated it was found that the worm had weakened them to such an extent that when the head was formed the plant became topheavy and broke down at the weakest point from force of gravity. * * * These heads were either entirely empty or filled with berries more or less shrunken. The bent or partly broken stems were, as a general rule, still adhering to the lower portion of the plant. This bending or breaking had taken place most frequently above a node or joint about 3 inches from the ground. Just below this breakage, and immediately above the joint, the culprits were to be found. In most cases but one puparium, but in a few cases two, three, or even more puparia could be detected. Such a puparium is the contracted and hardened skin of the larva or worm; it is of a glossy, chestnut-brown color, shading to yellowish brown toward the smaller end. If closely inspected it shows faint traces of sutures or segments. * * * These seed-like objects contain at this time (October) whitish larvæ or worms, and no pupæ have been detected inside of them up to this date. * * * Judging from the fact that only pupæ [puparia?—F. M. W.] can be found at this time, it would appear as if this insect hibernates in that stage. This is really the only one in which it could well pass our northern winters, being in that stage well protected by its old and thickened skin and by the stem of the plant. The puparia are inserted in the material of the upper part of the node, inaccessible to any moisture from the outside, as the stem above does not break off entirely, but simply bends in a more or less acute angle a short distance over them, thus preventing the entrance of water. Yet the culm is sufficiently fractured to permit a free exit of the future fly in spring. * * *

The damage caused by this insect in 1892 was by no means small. In many places fully one-fourth of the entire crop of wheat was destroyed, and in a great many more the losses amounted to at least one-tenth. As many places are badly infested, the total amount is quite large, and if no steps are taken to prevent it a repetition may become ruinous in 1893. Most farmers plowed their fields in the fall of 1892 or early in 1893, and consequently the losses in the latter year were small, and in 1894 but very few of these insects were to be found. The spring of this year [1896?—F. M. W.] being very wet, prevented extensive plowing, and the insects, not being disturbed or plowed under, again became a pest and caused considerable damage. The name "frit-fly" is a well-deserved one, as Swedish farmers call the worthless grain resulting from the attack of such flies "frits."

LIFE HISTORY.

As stated by Doctor Lugger, the life history is still very obscure, and it will require careful study and close observation to secure a knowledge of it over the country. The facts given by him in his report are unlike what has been observed farther south, but these differences are not sufficient to indicate that it was not this species that caused the injuries mentioned. Even if we assume that the insect reared in Kentucky by Professor Garman belonged to this species, we find that adult flies have been reared by others in May, late June, and early July, and again in September, thereby indicating three broods in the vicinity of latitude 40°, the species wintering as larvæ or pupæ, probably the latter, the flies emerging from these ovipositing in May, the adults from these appearing in June and July, these in turn giving origin to a fall brood in September, whose progeny winter over as stated. In more northern and inland sections of the country it seems that the fall brood may drop out and the one occurring farther south in midsummer pass the winter as puparia and the adults emerge the following spring.

FOOD PLANTS.

Either this has a greater range of food plants than *Oscinis carbonaria*, or else we have not learned much about those of the latter. As it is, the food of this species is so varied as to almost incline one to the suspicion that it stands accused of ravages that should be placed to the credit of another but for the facts supplied by Doctor Lugger. However, this variation in its bill of fare gives the farmer a still better opportunity of fighting it outside his grain fields.

DIFFICULTIES IN STUDYING HABITS.

The fact that maggots taken from wheat plants in a field develop these flies does not necessarily prove that other maggots attacking wheat in the same field will produce the same species of flies; therefore, descriptions drawn up from such collections may or may not be correct, and for the same reasons observations on the habits of such larvæ are liable to be incorrect. It is only by placing flies on plants known to be free from all other infestation and studying these that we shall be able to get at the truth in relation to anatomical and biological facts. An investigator will then know just which species he is dealing with, and whatever descriptions are drawn up from material secured in this manner and whatever observations are made upon them will be sure to be accurate so far as the species under observation is concerned. In no case has this been done, and as a consequence we have only a general knowledge of these insects, and any descriptions of the larvæ may or may not prove correct in future. Though there is a noticeable difference between the adult figured by Doctor Lugger as this species and the one figured by Professor Garman as *Oscinis variabilis* Loew? the figures of the larva and puparia are exceedingly alike. For the same reason any recommendations looking to the control of the pest in the grain fields must be made somewhat at random and aimed at Oscinidæ in general rather than at this particular species.

REMEDIAL AND PREVENTIVE MEASURES.

Over the area where winter wheat is cultivated the same measures that have been urged against the two wheat stem-maggots will apply equally well here, so far as we now understand the habits of this species. These are the destruction of volunteer wheat, the burning over of waste grass lands in winter and early spring, and late sowing of the grain in fall. In spring-wheat regions the experience of Doctor Lugger in Minnesota is strongly indicative of the effect of plowing the infested fields as soon as possible after the crop has been removed. He states that in the fall of 1891 and spring of 1892 not more than one-half of the acreage of wheat land was plowed, owing to unusually wet weather during these periods, and the pest that had gained a foothold, as it were, in 1891, meeting with no reverses on account of lack of plowing, simply continuing to increase in numbers, with the result that in 1892 it committed serious and widespread depredations. Where the fields can be burned over in fall or spring the result will, of course, be the extermination of the pest in such fields in the northern portions of the country, but farther south it is the grass lands that need to be burned over, since there is no way of reaching the insect hibernating in the winter-wheat plants. The fields of spring wheat in the North will, of course, be to some extent also protected by the burning over of the grass lands in fall or spring.

DESCRIPTION.

The difference between this species and *Oscinis carbonaria* have already been pointed out in the treatment of the latter species (see p. 55).

Larva.—This very closely resembles that of *O. carbonaria*, as is shown by the illustrations used by Doctor Lugger in his publications. He states, however, that the larva is of a greenish-white color when alive and just removed from the culm.

Puparium.—Here, again, it would be difficult to identify the puparium by either the illustration or description given by Doctor Lugger, as both closely resemble those given of *O. variabilis?* by Professor Garman. Doctor Lugger describes this as being of a glossy chestnut-brown color, shading to yellowish brown toward the smaller end, and showing faint traces of sutures or segments.

Of the other species of small Oscinidæ whose larvæ are found in and about the stems of growing grain I have already written, and it is impossible with our present knowledge of them to go into further details. Some of these may be destructive and some may not, as the fact of these having been reared from grain plants does not necessarily prove that they are destructive, as they may live upon the dead and decaying older leaves or they may simply inhabit the burrows made by other insects. The practical farmer will probably be able to meet their depredations by the same measures that have been recommended for those species with which we are the most familiar, at least until a more extended study can be made and more light thrown on their habits.

CONCLUSION.

In the foregoing it has been the aim of the writer to so present this subject as to enable the farmer to distinguish some of the more obscure enemies of his crops and prevent a peculiar and subtle shrinkage in the profits of his labors, and one that he can meet in most cases by simple measures that cost nothing except the time consumed in carrying them out during seasons or days of comparative inactivity on the farm. Not all of the ravages in the wheat fields are due to the Hessian fly, and, indeed, the crop reports are usually wholly unreliable in respect to the actual occurrence of this insect, except it be in cases of overwhelming numbers. One of the most practical preventive measures that can be applied against the Hessian fly will also prove of value in warring against these other pests, viz, late seeding of fall wheat in autumn; and a second measure, that of rotation of crops, will be found almost as valuable. Fighting insects demands a better system of farming, which of itself will pay in other directions, and the American farmer must calculate upon insect depredations as no small element in his business. Of what use is it to rear two blades of grass where but one grew before if he is to lose both of them by reason of insect attack? It is not the farm but the profits thereof that are lost through the devastations caused by injurious insects, and it costs the American farmer more to feed these insidious foes than it does to educate his children.

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U. S. DEPARTMENT OF AGRICULTURE.

DIVISION OF ENTOMOLOGY—BULLETIN No. 43.

L. O. HOWARD, Entomologist.

A BRIEF ACCOUNT

OF THE

PRINCIPAL INSECT ENEMIES OF THE SUGAR BEET.

BY

F. H. CHITTENDEN,
Entomologist in Charge of Breeding Experiments.

WASHINGTON:
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F. H. CHITTENDEN, *in charge of breeding experiments.*
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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., November 3, 1903.

SIR: I have the honor to transmit herewith for publication A Brief Account of the Principal Insect Enemies of the Sugar Beet, prepared by Mr. F. H. Chittenden, of this office. This paper has already appeared as a portion of Report No. 74 of the U. S. Department of Agriculture entitled "Progress of the Beet-Sugar Industry in the United States in 1902," for which it was specially prepared by your instructions. Owing to the subordinate position held by this article, the consideration of the subject was limited to the more prominent insect pests affecting sugar beet, and it was therefore impossible to enter into detail regarding these or other less injurious insects which are known to affect this important crop plant. Many of the species, especially those of greatest economic importance, have received more extended notice in other publications of this office, notably in Bulletins Nos. 19, 23, 29, 33, and 40, of the same series, and there are many others known to affect sugar beet which are not even mentioned, chiefly because we are not sufficiently conversant with their economic status.

I recommend the publication of this paper as Bulletin No. 43, of this Division.

Respectfully,

L. O. HOWARD, *Entomologist.*

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

A BRIEF ACCOUNT OF THE PRINCIPAL INSECT ENEMIES OF THE SUGAR BEET.

INTRODUCTORY.

Recent estimates made in the Department of Agriculture show that the world's production of sugar in 1902 amounted to nearly 10,000,000 tons, of which nearly 6,000,000 tons were manufactured from sugar beets.[a] The increase in the production of sugar from beets as compared with the production from cane has for many years been rapid and continuous. The first attempt to manufacture beet sugar in the United States was made in 1830. After numerous failures a successful factory was established in California about twenty-five years ago. In 1891 only three beet-sugar factories were in operation in the United States; but by 1902 the number had increased to 42, with many more in prospect. The manufacture of enough sugar to supply our home demand would require the operation of about 400 factories, or as many as there are in Germany, the principal sugar-beet growing country of the world. This in turn would require the cultivation of a very large acreage in sugar beets. More than $50,000,000 is reported to be invested in the beet-sugar industry in this country, and there is promise that the industry may, before a great many years, develop to the extent above indicated. Hence, any information which may be of use to sugar-beet growers is of immediate interest and practical value.

Although the beet-sugar industry is still in its infancy in America, already many insects—150 species in round numbers[b]—have been found to use beets as food, and, while comparatively few occasion losses of consequence, with the coming of years and the increase of cultivation of the sugar beet, other insects will acquire the habit of feeding upon it, and more extensive injuries may be expected each successive season.

If we leave out such forms of insects as blister beetles, army worms and cutworms, flea-beetles, leaf-beetles, and some few others, we may say that beets at the present time suffer comparatively little damage through insect ravages. The recent extension, however, of sugar-beet culture in this country has been the means of bringing to notice, through the publications of the Department of Agriculture and several of the State experiment stations,[c] a large number of insects not previously identified with attack on that plant.

A very considerable proportion of the insect enemies of sugar beet which are practically identical with those which affect table beet and

[a] Charles F. Saylor, Rept. No. 74, U. S. Dept. Agr., p. 124.

[b] Forbes & Hart, Bul. 60, Univ. Ill. Agl. Expt. Sta., 1900, pp. 397–532.

[c] See Bruner, Bul. 23 [old ser.], Div. Ent., U. S. Dept. Agriculture, 1891, pp. 11–18; Osborn & Gossard, Bul. 15, Iowa Agl. Expt. Sta., 1891, pp. 265–272; also numerous shorter articles.

spinach, subsist normally on wild plants of the same botanical order—the Chenopodiaceæ, or goosefoot family, which includes our common lambsquarters (*Chenopodium album*), spinach, and some related plants that are cultivated for ornament and as forage crops. Of the latter are several forms of saltbush (Atriplex). Many beet depredators also live on plants belonging to an allied family—the Amaranths—which contains many common weeds, including pigweed, as well as a few ornamental forms.

One of the earliest instances of injury to the beet reported in America is that furnished by our first economic entomologist, Harris,[a] in 1841. In quite recent years, however, several species have been so prominent as pests in fields of sugar beet that they have received names indicative of their beet-feeding habit, while a few take their common names from spinach. Among these are the beet army worm,[b] the beet webworm,[c] the beet or spinach leaf-miner,[d] spinach flea-beetle,[e] beet carrion beetle,[f] beet aphis,[g] European beet tortoise beetle,[h] and two species of leaf-beetles.[i] Of the various insects known to live on this plant, not more than about one-third, or 40 or 50 species, can be classed as noticeably destructive to it.

It is difficult to decide at this time, owing to the lack of study given the subject over the entire country where beets are raised, which forms of insects are of the highest importance. The different insects which have been mentioned specifically are more attached to beet and spinach than to other plants, and the greatest losses, if we take the entire country into consideration, are probably due to the ravages of flea-beetles, but they, as well as cutworms and similar groups, are so periodical or, more properly speaking, irregular in their depredations that an exact estimate of their economic status can not be made. Different species of leaf-beetles and caterpillars other than cutworms do more or less injury, and several blister beetles devour the foliage of sugar and table beets freely; most forms of the last, however, usually make their appearance so late in the season that, although defoliation may be excessive, comparatively little damage is accomplished. The same is true of some species of grasshoppers.

Beets until recently were comparatively free from subterranean insect enemies, but there are two forms of common farm pests, white grubs and wireworms, that affect underground portions of the plants and occasionally injure them; in addition to these, some kinds of root-lice and mealy-bugs injure the roots by suction, rendering them small

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[a] The species mentioned is the zebra caterpillar (*Mamestra picta*). Rept. Ins. Mass. Inj. to Veg., p. 328.

[b] *Caradrina exigua.*

[c] *Loxostege sticticalis.*

[d] *Pegomya vicina.*

[e] *Disonycha xanthomelæna.*

[f] *Silpha opaca.*

[g] *Pemphigus betæ.*

[h] *Cassida nebulosa.*

[i] *Monoxia puncticollis* and *M. consputa.*

and soft or spongy when they do not kill them outright. Some other sucking insects—plant-lice, plant-bugs, leaf-hoppers, and the like—occasionally injure the plants by absorbing their vital juices, but with some notable exceptions they are comparatively unimportant as beet pests.

Many of the most destructive or best known sugar-beet pests have received more extended notice in recent publications of the Division of Entomology, notably in Bulletins 19, 23, 29, 33, and 40, new series (from which the present article has been largely collated), in addition to other publications which have been cited in the introductory paragraph and others which will be mentioned in connection with the different species as they are considered.

In indicating methods of control to be observed for insects which are not special enemies of the sugar beet, it has been found necessary, owing to our somewhat imperfect acquaintance with all of the conditions which surround attack, to treat the subject in a general manner. The remedies for different forms and classes of insects are therefore considered as they occur upon the farm. Where deemed advisable, however, an effort has been made to limit remedial directions to the occurrence of many of these insects in fields of sugar beet. It may therefore be stated that as a general rule remedies prescribed for insects as these occur on their favorite food plants also serve for their destruction on other crops. Exception is made of insects such as the southern corn root-worm, which is a prime enemy of corn, though the beetles are usually to be found in beet fields, since the elaborate treatment which is often necessary in combating this pest on corn, need not be employed on beets and other crops where its injuries are comparatively insignificant.

LEAF-BEETLES AND FLEA-BEETLES.

Several leaf-feeding beetles of the family Chrysomelidæ, known as leaf-beetles and flea-beetles, are quite conspicuous as enemies of the sugar beet. Three of the leaf-beetles are apparently peculiar to beets among cultivated plants, injuring them both in the adult and the larval stage, while numerous flea-beetles, although as a rule general feeders, are even more destructive by attacking the plants early in the season, when they are least able to withstand injury.

THE LARGER SUGAR-BEET LEAF-BEETLE.

(*Monoxia puncticollis* Say.)

With the cultivation of the sugar beet in the West there has come to prey upon it a moderate-sized leaf-beetle, known in parts of New Mexico as the "French bug."[a] Its presence in beet fields was first

[a] See the author's article, Bul. 18, Div. Ent., U. S. Dept. Agr., p. 95.

noticed simultaneously in that Territory and in Colorado in 1898, when it did serious injury to crops. The beetles are gregarious, sometimes occurring "in swarms like blister beetles." Their brownish gray eggs are deposited in irregular masses, usually on the under sides of leaves. They hatch in about six days, and their larvæ or young commence feeding at once, continuing for nine or ten days, when they dig their way into the ground, a few days later coming forth as beetles. Although the beetles do much injury, the principal damage is sometimes accomplished by the larvæ, hundreds being found on a single small plant, which is either consumed or so injured that it shrivels and dies. In 1902 this insect did considerable injury to sugar beet in Colorado.[a] It feeds on several wild plants, blites (*Dondia americana* and *D. depressa*), Russian thistle (*Salsola tragus*), and saltbush (*Atriplex argentea*), is double-brooded according to Prof. C. P. Gillette,[b] and occurs throughout the summer.

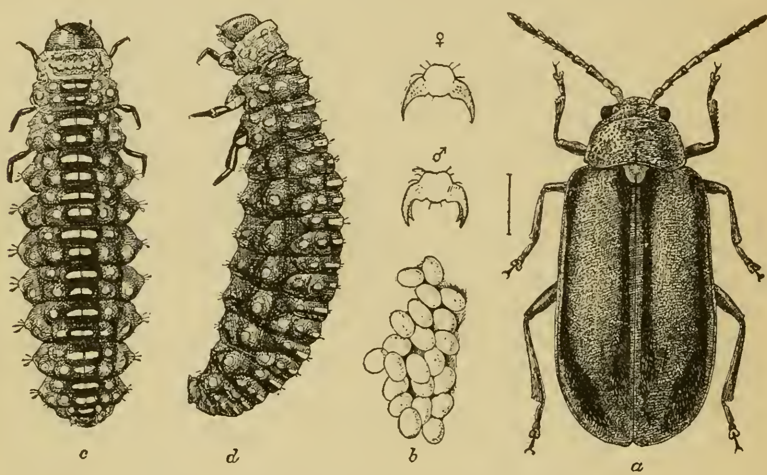

FIG. 1.—*Monoxia puncticollis: a*, female beetle; *b*, eggs; *c*, larva, dorsal view; *d*, larva, lateral view; ♂, claw of male; ♀, claw of female—all much enlarged, male and female claws more enlarged (author's illustration, Division of Entomology).

This species is related to the imported elm leaf-beetle, but is larger and differently marked. The beetle is quite variable, both as regards the markings and size, the length being from one-fourth to one-third of an inch. It is of oblong form, narrow in front. The color varies from pale yellow to entirely black, while the elytra or wing-covers are more or less distinctly striped. The surface of the thorax is coarsely and irregularly punctate. Five varieties or races are recognized. The beet-feeding form is illustrated in figure 1, *a*. The larva, shown in the same illustration, *c*, *d*, measures when full grown about one-third

[a] Bul. 40, Div. Ent., pp. 111–113.
[b] Twenty-fourth Rept. Colo. Agric. Expt. Sta., 1902, pp. 108–111.

of an inch in length. The general color is nearly uniform dark olive brown, the conspicuous piliferous tubercles being pale yellow, and the head and portions of the legs black. The eggs (*b*) are dull brownish gray, and the surface, as seen through a lens, is covered with septagonal and hexagonal areas.

A common variety of this species, not thus far noticed, however, in beet fields, is illustrated in figure 2. It has been observed in Nebraska, Texas, and Florida.

Remedies.—This and the Western beet leaf-beetle are apt to become important enemies of sugar-beet culture unless remedial measures are instituted. The general methods for the control of leaf and flea-beetles (see page 169) are all applicable, but a few remarks should be added in regard to particular remedies for these two species. Paris green, London purple, and paragrene have all been employed against the larger species with apparently good results when applied dry, mixed with flour, in the same manner as for the Colorado potato beetle. Against the Western species a spray of Paris green with whale-oil soap has been used with success, the beneficial effect lasting about six weeks, the beet leaves not being injured. There is no especial advantage in the addition of the soap, and the arsenical used alone or with Bordeaux mixture would have answered still better.

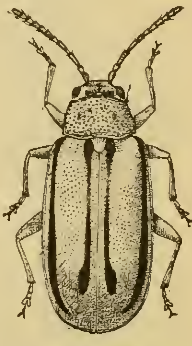

FIG. 2.—*Monoxia puncticollis*, variety—5 times natural size (author's illustration, Division of Entomology).

Two interesting facts brought out in the course of Professor Gillette's observations on the larger insect in Colorado are of value as indicating methods of control. It was observed that the beetles accumulated quite largely upon "mother" beets early in the spring, which suggests that if a few beets be left in the ground over winter they will serve as trap crops for the protection of the younger plants in spring. It was noticed also that the insect appeared to confine its injuries to plants growing in alkali ground or in close proximity to such soil. Hence such ground is to be avoided for the cultivation of beets.

THE WESTERN BEET LEAF-BEETLE.

(*Monoxia consputa* Lec.)

Garden as well as sugar beets are injured by this species, particularly along the Pacific coast. It first attracted attention in the years 1890 and 1891 in Oregon, where it did considerable injury (F. L. Washburn, Bul. 14, Oregon Agl. Expt. Sta., p. 11.). It eats holes through the leaves, in some instances leaving only a network of the original leaf, and this seriously interferes with the growth of young plants, which are sometimes killed.

This beetle (fig. 3) is smaller than the preceding, measuring only about one-sixth inch in length; is pale yellowish brown in color and moderately variable, some individuals being plain, while others are marked with black spots arranged in nearly regular series.

It is a Western species, but ranges as far eastward as the Dakotas, and is found in Montana, Utah, Colorado, Kansas, Arizona, and the Pacific States. There is no record of injury by the larva, but there is little doubt that it also affects this plant, and in much the same manner as does that of the larger sugar-beet leaf-beetle. Injury has been noticed in Oregon toward the end of August, continuing for six or eight weeks.

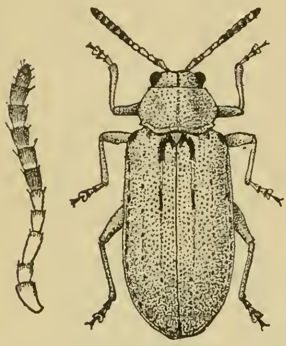

FIG. 3.—*Monoxia consputa:* beetle, 8 times natural size; antenna at left highly magnified (original, Division of Entomology).

THE SOUTHERN CORN ROOT-WORM.

(*Diabrotica 12-punctata* Ol.)

As this species is present everywhere in beet fields the year round, it is familiar to most beet growers. The adult is best known in the North as the twelve-spotted cucumber beetle, from its partiality for flowers of cucumber and related plants. In the South the young or larva is called the "bud worm" from its pernicious habit of burrowing into and eating young cornstalks soon after the germinating period.

The beetle (fig. 4) measures nearly one-fourth of an inch in length, is yellowish-green in color, and the elytra or wing-covers are marked with twelve black spots.

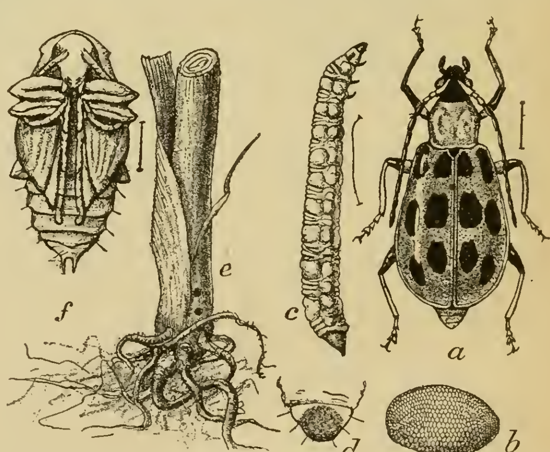

FIG. 4.—*Diabrotica 12-punctata: a,* beetle; *b,* egg; *c,* larva; *d,* anal segment of larva; *e,* work of larva at base of cornstalk; *f,* pupa—all much enlarged except *e,* which is reduced (reengraved after Riley, except *f* [original], Division of Entomology).

This beetle is practically omnivorous, feeding upon almost any form of vegetation upon which it happens to alight. Although very fond of flowers, it is liable to attack any portion of a plant, finding food on the foliage and other portions of most garden and many field crops, the flowers and leaves of fruit trees, and the bloom of many ornamental plants. The larva develops on the roots of grasses, as well as corn, and even on beans and some other plants. The beetles have been accused of being carriers of various plant diseases, and probably with justice, since they have a habit of flying frequently from one plant to another, feeding on each in turn. In the leaves of beets and other vegetables they make many small, irregular holes, and are capable of doing considerable damage when occurring abundantly on young plants. It is not known how many generations are produced during the year, but as the beetle is one of our earliest as well as latest species, it seems probable that two or perhaps three generations may be produced annually, at least in the more southern States.

Remedies.—Ordinary leaf-beetle remedies are applicable to this species in its occurrence on beets. On cucumber and other cucurbits, however, it is more troublesome, and must be treated in about the same manner as the striped cucumber beetle (see Circular No. 31, Div. Ent.). On corn it is still more difficult to control the root-worms, and this subject will be reserved for discussion elsewhere. The results of experiments with remedies are given in an article on this species by A. L. Quaintance (Bul. 26, n. s., Div. Ent., pp. 39–40).

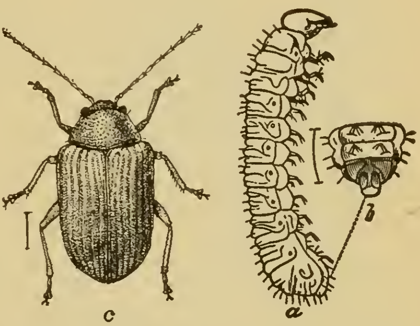

FIG. 5.—*Colaspis brunnea: a*, larva or root-worm; *b*, anal segment of larva from above; *c*, beetle—all enlarged (*a*, *b*, after Riley; *c*, original, Division of Entomology).

THE COLASPIS ROOT-WORM.

(*Colaspis brunnea* Fab.)

This species is best known as a depredator upon grape and strawberry, on which the larvæ also subsist, whence two of its vernacular names of grapevine colaspis and strawberry root-worm, but it has frequently been noticed on sugar beet in Nebraska and Illinois. It is also often found attacking the foliage of beans.

The beetle is common and well known. It is exceedingly variable, but typical specimens are yellowish or pale brown, dull or moderately shining, the elytra and legs are a little paler than the other portions. The form is oval, slightly oblong, and moderately convex, the general appearance being about as represented at figure 5, *c*. The larva[a] is a white cylindrical grub, about an eighth of an inch long, with a yellowish-brown head. The pupa is also white and has simple, incurved anal hooks.

This beetle has been recorded as doing more or less injury to several plants other than those mentioned, including potato, buckwheat, corn, clover, beans, cowpea, muskmelon, cotton, and some wild plants, including tick trefoil and New Jersey tea, and the leaves or blossoms of apple, pear, and willow. The larva has also been observed

[a] For particulars the reader is referred to 22d Rept. State Ent. Ill., 1903, pp. 145–149; also Bul. 9, n. s., Div. Ent., p. 21.

feeding on the roots of timothy and other grasses, and Indian corn, in addition to clover, strawberry, and grape, which would lead to the belief that the species might have been originally a grass-feeding one.

There is little doubt that the insect is single-brooded, and it has been surmised that it hibernates as a partly grown larva. The beetles which are to be found from June to September probably also hibernate.

THE BEET TORTOISE BEETLE.

(*Cassida nebulosa* Linn.)

An illustration of this species (fig. 6) and a short notice of it is presented, for the reason that it is one of the few insects which derive their common names from the beet, and because it is destructive to sugar beet in Europe. There is, moreover, some likelihood of its becoming a pest in our own country if it should ever be able to obtain a permanent foothold here. It is reported as having been observed in California in 1894, but as we have heard little of the insect since that time some doubt exists as to its actual establishment in America. It ranges through Europe and in Asia from Persia to Siberia, and it may be that it is destined to become cosmopolitan. Therefore beet growers should be warned against it. In Europe this beetle feeds on lambsquarters, Atriplex, and related plants, but when these plants become exhausted it devastates large areas of sugar beets. There are said to be two generations of the beetles produced annually, one appearing in August, the other in the autumn. The beetle is about one-fourth of an inch long and yellowish gray or pale green in color.

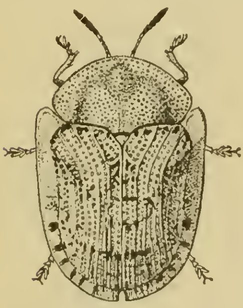

FIG. 6.—*Cassida nebulosa:* beetle, about 4 times natural size (original, Division of Entomology).

Remedies.—The same remedies advised against other leaf-beetles would apply to the present species.

THE SPINACH FLEA-BEETLE.

(*Disonycha xanthomelæna* Dalm.)

Flea-beetles are among the most important enemies of the sugar beet, and of growing importance, as recent reports bear testimony. No less than a score of species have been observed to attack beets. Among the most destructive of these are the spinach flea-beetle, the pale-striped flea-beetle, and the black and red-headed flea-beetles, well-known forms in the East; but in some portions of the West and elsewhere others do more damage. They are most troublesome on very young plants.

Reports of injuries by the spinach flea-beetle to cultivated plants are rapidly increasing, although it continues to live by preference on weeds and wild plants. The crops most injured are beets, spinach, and saltbush; and natural food plants are chickweed and lambsquarters. The leaves of these plants are riddled with holes, chiefly the work of the larvæ, but also of the beetles, and gardeners complain that spinach may be so badly worm-eaten that it is impossible to offer it for sale. Considerable injury to beets was observed by the writer in 1900, and during 1902 and 1903 the insect has been the most conspicuous species on sugar beet in and near the District of Columbia.

The larvæ, as well as beetles, drop quickly upon being disturbed, and as the former are inconspicuous in appearance, and the latter feign death, the miscreants are apt to elude recognition, the early injury produced being frequently ascribed to cutworms and the later damage to other insects. Frequently from 15 to 20 larvæ live on a single leaf. They feed mostly on the under surface.

The beetle (fig. 7, *a*) is shining black, sometimes with a greenish or bluish luster. The prothorax and abdomen are red or reddish yellow, and the legs and antennæ pale yellowish. It measures less than one-fourth of an inch. The buff or orange eggs (*b*, *bb*) are deposited in masses. The mature larva (*c*) as it occurs on sugar beet is dull leaden gray, with darker head and still darker brown mouth parts, but on red and purple beets it takes on the color of the plant attacked. This is a native species and of exceptionally wide distribution, its habitat extending from New England to Montana, and from British America to Florida and Texas. It is one of our earliest spring visitors, appearing in the first warm days of March in the Atlantic States, and continuing abroad some years through November. Two generations occur in the District of Columbia, the first usually produced on chickweed, and later ones on beets, spinach, and other plants. It is a prolific insect, as many as 180 eggs having been observed to be deposited by a single female.[a]

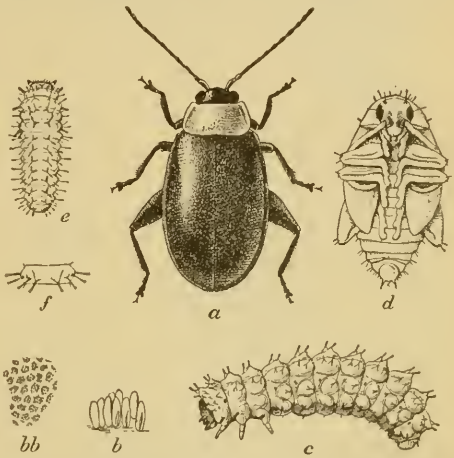

FIG. 7.—*Disonycha xanthomelæna*: *a*, beetle; *b*, egg mass, showing mode of escape of larva at right; *bb*, sculpture of egg; *c*, full-grown larva; *d*, pupa; *e*, newly hatched larva; *f*, abdominal segment of same—*a*, *c*, *d*, five times natural size; *b*, *e*, more enlarged; *bb*, *f*, still more enlarged (author's illustration, Division of Entomology).

[a] A more complete account of this flea-beetle is given in Bul. 19, n. s., pp. 80–85.

THE PALE-STRIPED FLEA-BEETLE.

(*Systena blanda* Mels.)

This species, a beet feeder of long standing, has in recent years come to the front as an important enemy to sugar beets, and table beets are also affected. In 1899 and 1900 much injury was done to sugar-beet fields in Michigan, some having been practically destroyed while the plants were quite young. During 1900 much injury was done in Colorado, the beetles appearing in swarms of millions and practically killing plants of two or three weeks' growth. Older plants were considerably checked in development, but not destroyed. The next year beets were injured in South Carolina and Indiana.

This is one of our commonest, most nearly omnivorous, and most destructive flea-beetles. It measures about an eighth of an inch, is cream-colored, with nearly black abdomen and eyes, and striped wing covers (fig. 8, *b*). The larva is white and slender, with light brownish-yellow head. It is an American species and of rather wide distribution, from New Jersey and Pennsylvania southward to Georgia, and westward to California.

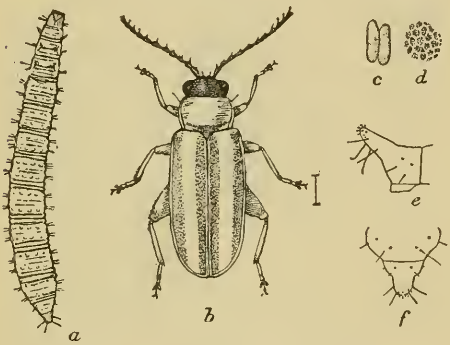

FIG. 8.—*Systena blanda*: *a*, larva; *b*, beetle; *c*, eggs; *d*, sculpture of egg; *e*, anal segment, from side; *f*, same from above—*a–d*, six times natural size; *e*, *f*, much enlarged (author's illustration, Division of Entomology).

The pale-striped flea-beetle, though a general feeder, is particularly fond of the foliage of beets and beans. Potatoes and corn it also injures very much, while considerable damage to melons and other cucurbits, turnips and other crucifers, tomatoes, peas, carrots, and eggplant has been observed. The beetles also attack strawberry, clover, cotton, oats, and peanuts, and injure the leaves of pear, as also pear grafts, by eating out the terminals, thus stunting the growth of the trees. They sometimes do severe injury in three or four days.

The species hibernates as a beetle, and appears above ground in the vicinity of the District of Columbia early in June; egg laying evidently continues through that month and to the middle of July, if not two or three weeks later; injury is usually due to the beetles upon their first appearance; and almost any valuable crop may be injured, either in the absence or presence of the wild food plants.

The larvæ live below ground, and have been observed by the writer and others feeding on the roots of corn, lambsquarters, and Jamestown weed. They probably live also on pigweed (Ambrosia), cocklebur (Xanthium), and other weeds, as the beetles are commonly found on these plants.

THE BANDED FLEA-BEETLE.

(*Systena tæniata* Say.)

The banded flea-beetle also frequently attacks beets, beans, and other vegetables, particularly in the West and Southwest. It has similar habits to the preceding species and similar structure; it was, in fact, until quite recently very generally confused with the pale-striped form, and many references to injuries by this species are really due to the latter. Like the latter it varies considerably as regards color and punctation. It is polished black, with white stripes. A common dark form of the beetle is shown in figure 9.[a]

FIG. 9.—*Systena tæniata*, dark variety—about 6 times natural size (author's illustration, Division of Entomology).

THE RED-HEADED FLEA-BEETLE.

(*Systena frontalis* Fab.)

This species (fig. 10) resembles in its habits the two flea-beetles that have just been mentioned. Its color is shining black throughout except the major portion of the head, which is red. It has been known as an enemy of beets since 1891. It also attacks potato and beans, but is not restricted to vegetable crops, being quite fond of the foliage of fruits, including grape, gooseberry, pear, and others. It inhabits practically the entire arable region east of the Rocky Mountains, including southern Canada and the Southern States (Bul. 33, n. s., Div. Ent., pp. 111–113).

FIG. 10.—*Systena frontalis*—much enlarged (author's illustration, Division of Entomology).

THE SMARTWEED FLEA-BEETLE.

(*Systena hudsonias* Forst.)

From the red-headed flea-beetle this differs in being uniformly shining black. Otherwise the two species are very similar. Taken all in all, it is perhaps the most abundant of the flea-beetles which have been mentioned, but, although it shows a fondness for a number of crop plants, including sugar beet, potato, grape, beans, and sweet corn, it is much more confined to weeds (L. c., pp. 113–114).

The larval habits of the three species last mentioned have not been positively ascertained, but there is little doubt that they will be found to be much the same as those of the pale-striped flea-beetle, since the beetles of all of them occur in greatest numbers on the same species of weeds, and, even when occurring in moderate abundance, seem to show little preference.

[a] This and the preceding species are discussed in Bul. 23, n. s., Div. Ent., p. 23.

THE WESTERN CABBAGE FLEA-BEETLE.

(*Phyllotreta pusilla* Horn.) [a]

In some of the Western States not inhabited to any extent by any of the preceding species there is a small dark-colored flea-beetle uniformly deep polished olive green, with the surface irregularly punctate (fig. 11) which, as its English name indicates, affects more particularly cabbage and related crops. During 1901 it was observed doing considerable damage to sugar beet in portions of Colorado. It prefers the younger plants, and as instance of its destructiveness one grower reported that he had not raised a turnip for seven years on account of its ravages. Between 10 and 20 acres of corn were reported destroyed on one farm in twenty-four hours, the beetles sometimes coming in swarms like black clouds and covering the plants. This flea-beetle ranges from the Dakotas to Mexico, and westward to southern California, being found in numbers at high elevations in the Rocky Mountain region.

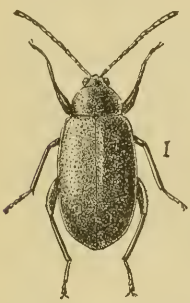

FIG. 11.—*Phyllotreta pusilla*—much enlarged (after Riley, Division of Entomology).

REMEDIES.

The arsenicals, especially Paris green, are the most useful remedies for leaf-feeding beetles, and since Bordeaux mixture is extremely distasteful to flea-beetles, this, if mixed with the insecticide and applied as a spray, is more effective than when the arsenical is used dry. Against some species, however, Paris green mixed with 20 parts of flour and dusted on infested plants has been found satisfactory, while kerosene emulsion and even strong soap washes have been found useful in combatting others. When the plants are quite young the spray can not be so well used as after they have attained larger growth, but the dry mixture can then be applied with best results. Bordeaux mixture used alone is valuable as a deterrent.

Clean culture is also of the greatest value. It consists in keeping down weeds which serve as food for the beetles and as breeding places for their larvæ. Against the spinach flea-beetle we have to destroy the chickweed and lambsquarters of the vicinity and to avoid the planting of beets and spinach in ground which has become overgrown with these plants. For the pale-striped flea-beetle, lambsquarters, cocklebur, and pigweed should be destroyed, while for insects like the smartweed flea-beetle practically all weeds in the vicinity must be pulled up and destroyed, as this insect feeds on nearly all forms of useless vegetation. The time for performing this work varies according to

[a] In early publications, for example, in the Report of this Department for 1884, p. 308, this insect was mentioned as *Phyllotreta albionica* owing to the fact that the two species had not been separated, *albionica* being the older name.

the species concerned, and with locality and season. In general terms, it may be said that the best time is after the beetles have laid their eggs and before the young or larvæ have attained full development. For most species this would be about three weeks after the first appearance of the beetles in numbers. A spraying of the upper surface is sufficient for most flea-beetles, but for the spinach flea-beetle it is necessary to apply a spray to both the under and upper surfaces in order to reach the larvæ which feed in exposure on the lower surfaces of plants.

THE BEET AND SPINACH CARRION BEETLES.

Among insects particularly attached to beet and spinach are two, known respectively as the beet and the spinach carrion beetles. They are nearly unique among carrion beetles (Silphidæ) which subsist chiefly on decomposing animal matter, this being the normal habit of the family. The two species in question are also found under carcasses and in garbage. From their dual habit of living both on carrion and on beets and spinach they derive their English names.

THE BEET CARRION BEETLE.

(*Silpha opaca* Linn.)

This species is mentioned in the preface as particularly attached to the beet. In some parts of Europe it is a very serious pest, more particularly in Germany, France, Austria, and England, although it is rather generally distributed on that continent, occurring in Siberia. In Germany it has been described as "by all odds the most troublesome pest" with which beet growers have to deal. The species was identified in 1880 from specimens collected in California and "Hudson Bay," and it seems probable that it was introduced on the Pacific coast, and has recently made its way to Nebraska, where it was found attacking beet in 1891.[a] There is some danger that at some future time it may become a more serious pest, such as it now is in its native home.

The beetle is black and of similar appearance to our common carrion beetles. The body is elongate, or oblong-oval, with the sides comparatively parallel. It is much flattened, and the elytra at the sides are thin and slightly reflexed or turned up. There is also a small prominence near the end of each, the middle costa or ridge of the elytron extends nearly to the posterior margin, and the tip of the abdomen is dull red. The length is about three-fourths of an inch.

The larvæ are shining black, and of similar appearance to our common sowbugs (Oniscus), creatures commonly found in fence corners and in cellars, and they, with their parents and others of their kind,

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[a] Bruner, Bul. 30 (old series), Div. Entomology, p. 40.

occur under carcasses of small animals, such as rabbits and birds, and in garbage.

The eggs are probably laid usually in decomposing material, but it has not been ascertained where they are deposited in beet fields.

The larvæ are nocturnal, feeding chiefly in the evening and early morning, and concealing themselves during the heat of the day about the roots of the plants affected. They first attack the parenchyma or outer surface of a leaf, leaving the skeleton more or less intact; but when in numbers they consume entire leaves, sometimes eating them down to the ground. Afterwards they attack the roots. Where the leaves are not severely eaten the plants recover, but if the foliage is destroyed the plants usually die. The species is probably single-brooded. As soon as the larvæ become full fed injury ceases and the plants, if not too seriously damaged, begin to take on new growth. Larvæ descend into the soil to a depth of three or four inches and there change to pupæ and afterwards to beetles, in which stage they pass the winter undisturbed and free from natural enemies until the following spring, when they reappear.

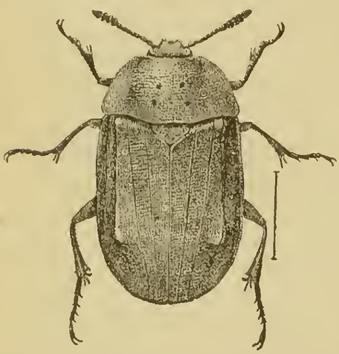

FIG. 12.—*Silpha bituberosa:* adult—much enlarged (original, Division of Entomology).

THE SPINACH CARRION BEETLE.

(*Silpha bituberosa* Lec.)

This species resembles the preceding, both in appearance and habits, but differs in some important particulars, being a native species and restricted, so far as injurious occurrences are concerned, to the Northwest Territories and neighboring portions of British America. It occurs, however, also in northern Kansas, from which State it was originally described in 1859, and in Wyoming and Montana. Unlike the preceding species, it attacks other vegetation than beets, although it seems probable that it fed originally on plants of that family, such as lambsquarters and another weed native to the Northwest (*Monolepis nuttalliana*). Other food plants are squash and pumpkin. The insect seems capable of being quite destructive to all of these crops. Some vines of the pumpkin have been entirely destroyed. In Alberta the larvæ have been reported as swarming in gardens in the spring, devouring leaves of spinach and beet.

The spinach carrion beetle (fig. 12) is much broader than the beet carrion beetle, being more nearly oval, whereas the latter is elongate oval. It measures nearly half an inch and is of the same black color. The larva is polished black and does not appear to have been differentiated from that of the preceding.

In its life history it doubtless closely resembles the European importation in feeding on both carrion and vegetation. Whether or not the beetles also injure plants does not appear to be known. Attack by the larva begins in the latter part of May, extending through June, and probably into July in the more southern and warmer range of the species.[a]

REMEDIES.

The remedies in use against the Colorado potato beetle are applicable to these carrion beetles. Paris green, applied either dry or in spray, as directed for leaf beetles, and clean culture are about all that are necessary, but it is also advised in the treatment of the native species that the weed Monolepis be sown in the vicinity of spinach, beets, and gourd crops subject to attack, to serve as a lure to draw the insects from the crops. On the trap plants they can be more easily destroyed, and by various means.

BLISTER BEETLES.

Blister beetles are among the most conspicuous of all enemies of the sugar beet, no less than a dozen species having been observed doing more or less injury to this crop. One or more species are generally found in beet fields, and, in fact, the arable regions of the United States are probably never free from them. In the East four or five species are common, and in the Southwest there are a few more extremely destructive species. Most blister beetles are better known as potato pests, but next after potatoes beets appear to be the favorite food of many of them. After this they attack other vegetable crops, some favoring beans, peas, and other legumes, while almost any of them will attack whatever comes next in their line of march. They are gregarious, congregating in great numbers, and some have the truly migratory habit, feeding voraciously, running with great rapidity, and flying from time to time. Thus it happens that they frequently descend in such numbers on a field that an entire crop is ruined beyond recovery in a few days, when the insects disappear and are perhaps seen no more until the following year. After the departure of one species of blister beetle another frequently follows, to be replaced by a third, and so on.

Some species, though apparently very destructive, appear so late in the season that, although beet plants are sometimes nearly defoliated, a fair crop may be gathered in spite of the loss of the leaves, a new growth of which is sometimes put forth. The roots, morever, are not touched.

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[a] General accounts of this insect have been published by Dr. James Fletcher. (Rept. Ent. Can. Exp. Farms for 1893 [1894], pp. 20, 21; for 1897 [1898], page 198, etc.)

In their life history blister beetles differ greatly from other Coleoptera in that they undergo a more complicated series of metamorphoses which will be explained and illustrated in the account of the striped blister beetle which follows.

Blister beetles are not an unmixed evil, since they do some good in their larval stage to compensate in a measure for the harm the beetles occasion to our crops, for the habit of the larvæ of destroying grasshopper eggs renders them of material aid in keeping these pernicious insects in check. This is especially true in the Western States, where both blister beetles and grasshoppers abound. But the benefits derived are really more than counterbalanced by the losses occasioned in fields and gardens; hence, insecticides and other measures should be employed to destroy the beetles when they occur in harmful numbers.

As blister beetles are to be found in practically all fields of sugar beet, and are among the most prominent enemies of this plant, it is purposed to consider several of the most abundant species.

THE STRIPED BLISTER BEETLE.

(*Epicauta vittata* Fab.)

Before the advent of the Colorado potato beetle in the East this was our most destructive potato insect, and probably because it is also

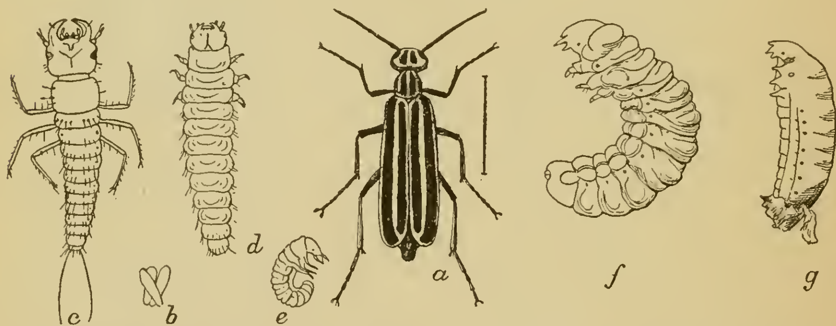

FIG. 13.—*Epicauta vittata*: *a*, female beetle; *b*, eggs; *c*, triungulin larva; *d*, second or caraboid stage; *e*, same as *f*, doubled up as in pod; *f*, scarabæoid stage; *g*, coarctate larva—all except *e* enlarged (after Riley, except *a*; original, Division of Entomology).

striped is often called the "old-fashioned potato bug." It is abundant and well known east of the Rocky Mountains, of common occurrence on sugar and table beets, and as its life history is typical of injurious forms of this group it may properly receive first attention. The beetle can be easily identified by means of the illustration (fig. 13, *a*). It is about half an inch long, and there are two black stripes on each wing-cover, alternating with yellow.

The eggs are laid in small masses (*b*) on plants or upon the ground. From each hatches a small long-legged larva, called a "triungulin" (*c*), which runs actively about in search of a grasshopper egg pod, which it enters and devours the contents. After a time it casts its skin and assumes what is termed the "caraboid" or second larval stage (*d*, *e*); and with another molt it resembles a white grub, the "scarabæoid" larval stage (*f*). When a larva has finished its quota of locusts' eggs it undergoes a fourth molt and forms within its own skin what is known as the coarctate larval stage (*g*), and in this condition usually passes the winter. In the spring another larval molt takes place, and with the last shedding of its skin the insect enters upon the true pupal stage, and in due time transforms to a beetle.[a] The pupa of a related species is illustrated in figure 16.

This species also does injury to beans, peas, tomato, turnip, radish, melons, corn, clover, and alfalfa. It was the cause of a serious outbreak in Michigan in the latter part of June and the first part of July, 1900. Corn plants about six inches high and clover suffered severely, the reason being that the potatoes grown there, being all late varieties, had not come up, and more palatable food was not available.

The writer has seen hordes of this species traveling in much the same manner as army worms, and feeding with such voracity that scarcely a beetle flew when plants on which they were congregated were approached. When a "flock" starts to feed on one form of food plant it continues on this until all plants in sight have been devoured, when the beetles have recourse to other plants that are palatable to them. This trait has also been observed in other species, especially in the margined blister beetle.

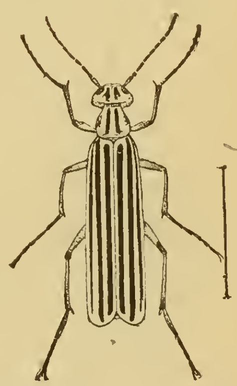

FIG. 14.—*Epicauta lemniscata*—enlarged (original, Division of Entomology).

THE THREE-LINED BLISTER BEETLE.

(*Epicauta lemniscata* Fab.)

This blister beetle very closely resembles the preceding; in fact, the two are frequently confounded, and injuries inflicted by one species are apt to be attributed to the other. The form under consideration (fig. 14) is a little more slender than the striped blister beetle, has three stripes on each wing-cover instead of two, and is a little longer. It is very abundant southward, and, although perhaps primarily a potato pest like most of our noxious blister beetles, is also extremely fond of beets. During different years we have received complaints of this species and of extensive damage in Florida, South Carolina, and Texas to cabbage, potato, squash, and to beet tops, as also to alfalfa. In the vicinity of Horton, Tex., in 1896, the last-mentioned crop was said to be a failure, owing to the depreda-

[a] Particulars in regard to these peculiar transformations are given in articles by C. V. Riley, Am. Nat., Vol. XII, p. 286; Vol. XVII, p. 790.

tions of this blister beetle. During 1902 we received reports of injuries by it in Florida to tomato, potato, sweet potato, eggplant, turnip, cabbage, cowpea, and beet, beet tops being preferred to all other vegetables.

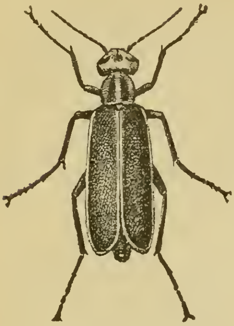

FIG. 15.—*Epicauta marginata*—enlarged (original, Division of Entomology).

THE MARGINED BLISTER BEETLE.

(*Epicauta marginata* Fab.)

One of the commonest Eastern species is the margined blister beetle (figs. 15 and 16). In the writer's experience it appears to be more partial to beets than to any other useful plant. Entire plantings are often seen almost completely defoliated. In a climate like that of the District of Columbia, it occurs so late that no material harm is done, the roots having made nearly complete growth when the insect appears in its greatest abundance, in late July and in August. It is known as an important enemy of beans, potato, and tomato, and attacks aster, clematis, and other ornamental plants.

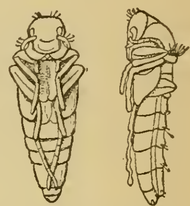

FIG. 16.—*Epicauta marginata*: pupa—enlarged (original, Division of Entomology).

THE GRAY BLISTER BEETLE.

(*Epicauta cinerea* Forst.)

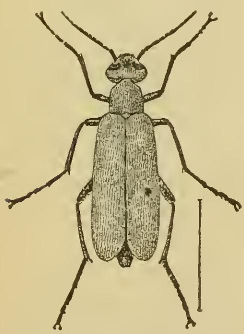

FIG. 17.—*Epicauta cinerea*—about twice natural size (original, Division of Entomology).

This species (fig. 17) is of the same form and general structure as the preceding, but is of a uniform gray color, lacking the sutural and lateral margins which give the name to the margined blister beetle. The habits of the two species are practically identical; in fact, the latter is believed by some to be only a variety of the margined species.

FIG. 18.—*Epicauta maculata*—nearly three times natural size (original, Division of Entomology).

THE SPOTTED BLISTER BEETLE.

(*Epicauta maculata* Say.)

The southwestern portion of the United States is the home of many species of blister beetles not found in the North and East. Among the most abundant of these is the spotted blister beetle (fig. 18). Its body is covered with fine gray hairs, with small rounded areas on the elytra, through which the natural black of the body shows, giving it the appearance of a gray insect finely dotted with black. It is more or less abundant from Texas and New Mexico northward to South Dakota, and in California and Oregon. It has been known as a beet pest since 1875,[a] and was reported very generally upon sugar beet, potato, and clover in South Dakota in 1897.[b] In August, 1902, Mr. J. L. Webb observed numbers eating leaves of beet at Elmore, S. Dak.

Fig. 19.—*Epicauta pennsylvanica*—enlarged (original, Division of Entomology).

THE BLACK BLISTER BEETLE.

(*Epicauta pennsylvanica* De G.)

The black blister beetle (fig. 19) is a familiar object to nearly everyone from its occurrence on golden-rod, aster, and related wild plants, while the farmer is quite too well acquainted with it as an unwelcome visitor to his potato patch and to various other vegetables. Florists know it under the name of "aster bug," from the severe injuries which it does to asters and which they are unable entirely to prevent. It is uniformly black, without polish, and its length varies from a little more than a quarter to half an inch. It is well distributed in the region east of the Rocky Mountains, and does most injury between the Atlantic States and Texas. Its time of appearance is more or less coincident with the blossoming of the golden-rod, from June to October according to locality, and as a rule it appears later than other species. It is one of the worst insect enemies of potato, beet, and aster, and is also destructive to carrots, beans, cabbage, corn, mustard, clematis, zinnia, and other flowering plants.

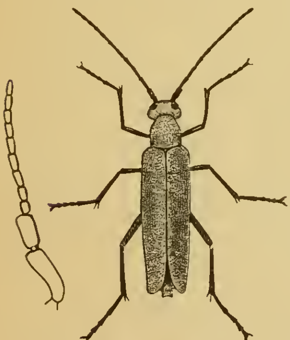

Fig. 20.—*Macrobasis unicolor:* female beetle at right, twice natural size; male antenna at left, greatly enlarged (author's illustration, Division of Entomology).

THE ASH-GRAY BLISTER BEETLE.

(*Macrobasis unicolor* Kby.)

This is one of our commonest Eastern species (fig. 20), and although most destructive to beans, peas, and other leguminous plants, is also a serious enemy of beets, potato, and tomato, and attacks besides sweet potato and some flowering plants.[c]

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[a] Packard, U. S. Geol. Surv. for 1875, p. 731.
[b] D. A. Saunders, Bul. 57, So. Dak. Agl. Ex. Sta., p. 52.
[c] Yearbook U. S. Dept. Agr. for 1898, pp. 249–250.

THE IMMACULATE BLISTER BEETLE.

(*Macrobasis immaculata* Say.)

As with some of the following species, this insect, although common, has not been much studied; but we know of its having injured beets in Kansas as early as 1897, and during 1902 it was destructive to sugar beet in Colorado. Among other food plants are potato, tomato, and cabbage. It is one of our largest blister beetles, and is gray or yellow in color.

THE TWO-SPOTTED BLISTER BEETLE.

(*Macrobasis albida* Say.)

During 1902 this blister beetle was destructive in Indian Territory, in one case devouring a field of sugar beets in a single day. Although an extremely common species from Kansas to Texas and New Mexico, little has been published in regard to its habits until very recently. Like others of its kind it favors vegetable crops, which include tomato, potato, and some others. It is evidently an old beet enemy, as we have record of its being very injurious to this crop in Kansas a decade earlier than the case reported.

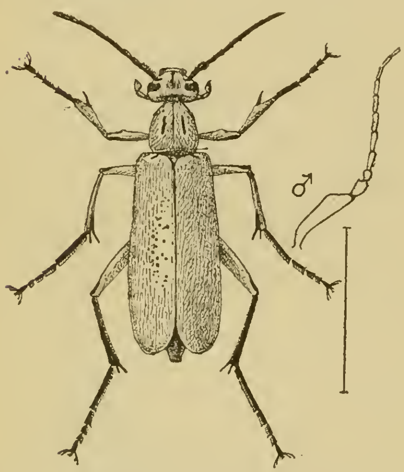

FIG. 21.—*Macrobasis albida:* twice natural size (original, Division of Entomology).

This is also a large species (fig. 21), gray or yellowish in color, with the thorax marked with two nearly parallel lines. It measures about an inch or an inch and a half in length.

THE SEGMENTED BLACK BLISTER BEETLE.

(*Macrobasis segmentata* Say.)

Injury by this blister beetle to beets was reported to this office in 1897, when a considerable proportion of crops of beets, as well as potato, tomato, and cabbage, was being destroyed in Kansas, the beetles being described as coming in large swarms, settling down in fields, and devouring and ruining crops in a few hours. It is one of the larger species of the group, sometimes attaining a length of about an inch. It is of robust form, uniformly dull black, except for an occasional narrow fringe of cinereous hairs on the base or apex of the thorax. Its range extends from Kansas well into Mexico.

NUTTALL'S BLISTER BEETLE.

(*Cantharis nuttalli* Say.)

This species has several times been noted as injuring beets. The beetle (fig. 22) is large and beautiful, usually of a bright metallic green, the head and thorax having a coppery luster, the wing-covers often purple. Its habitat extends from the Mississippi region to the Rocky Mountains and from Canada to Nebraska.[a]

Notes on the habits of this and several other species which have been considered are published in Bulletin No. 40 (new series) of the Division of Entomology (pp. 114–116).

REMEDIES.

Paris green is one of the best remedies for blister beetles when they occur on beets, potatoes, and most other crops. It may be applied dry, mixed with 10 to 20 parts of flour, plaster, or air-slaked lime, or in the form of a spray, also mixed with lime or Bordeaux mixture, at the rate of a quarter of a pound of the poison to 40 gallons of the diluent. Repeated applications are sometimes necessary, since the poisoned beetles are replaced by others.

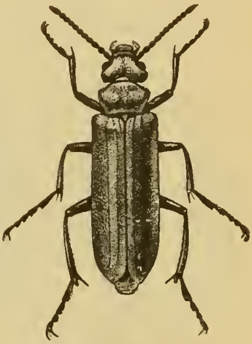

FIG. 22.—*Cantharis nuttalli:* female beetle, one-third larger than natural size (author's illustration, Division of Entomology).

Owing to the rapidity with which many species work, frequently in swarms of thousands, poisons are of little value. We must, therefore, resort to mechanical measures for their destruction, and in the employment of these promptness and thoroughness are the essentials. A remedy which is employed with success in the Western States consists in sending a line of men and boys through infested fields to drive the beetles before them until they alight on a windrow of hay, straw, or other dry vegetable material which has previously been prepared along the leeward side of the field. When the beetles have taken refuge in such a windrow, it is fired and the beetles are burned. The beetles may be destroyed by sweeping them into a net, such as is used by insect collectors, and throwing the captured insects into a fire; or by beating them into large pans of water on which there is a thin scum of coal oil. The latter remedy is successful over small areas.

After what has been said concerning the voracity of these beetles it is almost superfluous to add that whatever remedy is employed should be applied at the outset of attack in order to be of substantial value.

[a] Yearbook U. S. Dept. Agr. for 1898, pp. 250–251.

SNOUT-BEETLES OR WEEVILS.

A few species of snout-beetles or weevils have been observed attacking sugar beet at various times, but with the exception of the imbricated snout-beetle these insects are of little importance as beet pests; in fact, only one species other than that habitually does material harm to beet plants. The species in question (*Tanymecus confertus* Gyll.) was once notably injurious to sugar beet in Nebraska. It was observed by Professor Bruner first on cocklebur, lambsquarters, and smartweed, after devouring which it completely destroyed the beets in a 12-acre field. Injury by this class of insects in beet fields is by the beetles, the larvæ feeding on the roots of weeds and wild plants.

THE IMBRICATED SNOUT-BEETLE.

(*Epicærus imbricatus* Say.)

The imbricated snout-beetle is a common insect of the field, garden, and orchard, and capable of committing considerable injury to a variety of useful plants including sugar beet and various other vegetables, such as beans and pease.

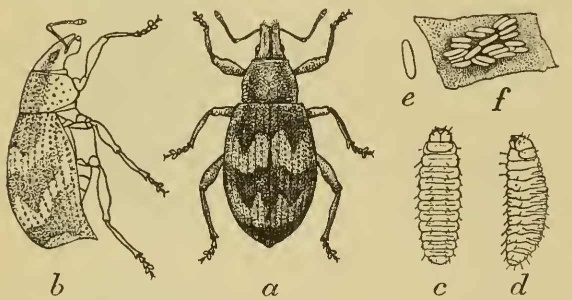

FIG. 23.—*Epicærus imbricatus:* *a*, female beetle; *b*, same from side; *c*, newly hatched larva; *d*, same from side; *c*, egg; *f*, egg mass.—*a*, *b*, about three times natural size; *f*, two times; *c*, *d*, *c*, more enlarged (author's illustration, Division of Entomology).

It is one of our largest snout-beetles, measuring nearly half an inch in length, and has the body covered with minute imbricated scales (whence the insect's name), the lighter portions appearing brownish gray, and the darker light brown, forming a pattern as shown in figure 23, *a*, and *b*. The head is prolonged into a short broad snout, with elbowed antennæ and the elytra or wing covers terminate in a point. Both sexes are wingless.

It is well distributed, occurring in most States, except the more northern ones, east of the Rocky Mountain range. It does not appear to be found north of the Upper Austral life zone. This distribution includes localities from the neighborhood of New York City southward to Texas and westward to Colorado and Utah.

In addition to the plants that have been mentioned as furnishing food for this species, it has been observed doing more or less injury to onion, radish, cabbage, cucumber, watermelon, muskmelon, squash, corn, potato, and tomato, among vegetables; apple, cherry, and pear trees; raspberry, blackberry, and gooseberry bushes; and to feed on grasses and clover, and some forms of weeds.

The larva is subterranean in habit, but the mature larva and the pupa are unknown, as is also the larval food plant. A female beetle kept by the writer from May till July deposited eggs almost daily, 540 in number, and it was not known how many eggs had been laid prior to that time. The beetle possesses the habit so common to snout-beetles of "playing 'possum" or feigning death when disturbed, dropping off its food plant on the slightest disturbance and remaining for some time before resuming activity.[a]

A beetle parasitized by a fungus (*Sporotrichum globuliferum?*) is illustrated in figure 24.

The imbricated snout-beetle is one of many species of insects which are sporadic as regards injurious attack and troublesome only in seasons following a year which has been favorable to the increase of individuals. The beetles are not restricted to wild plants even in years of scarcity, but are found over the area which they inhabit on cultivated or other useful plants every year. Fortunately the beetle is not only irregular as to destructive occurrences, but is omnivorous as well, subsisting on one plant quite as well as another, thus distributing attack.

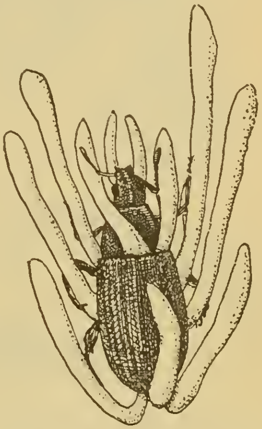

Fig. 24.—*Epicærus imbricatus:* beetle attacked by fungus—three times natural size (author's illustration, Division of Entomology).

Remedies.—This species will yield to the same remedies in use against the Colorado potato beetle. On plants resistant to arsenicals, such as potato, Paris green applied as a spray at the rate of a pound to 100 gallons of water is effective, while on less resistant plants, such as peach and bean, a weaker spray—about 1 pound to 150 gallons of water—or one in which arsenate of lead is the poison, is necessary to avoid scalding the foliage. Arsenicals can also be used dry, mixed with about 10 parts of cheap flour or lime, and applied to the infested plants by means of a hand bellows.

The beetles may be readily dislodged from affected plants by jarring them with a pole or stick upon "curculio catchers" of strong cloth stretched on frames and mounted on wheels or runners. If the cloth is saturated with kerosene, it will kill them; or, as they make little or no effort to escape, they may be easily taken from the "catchers" and killed by burning or by pouring scalding water over them.

Eventually this snout-beetle will probably become rare owing to its being wingless, when it may be replaced by other species having well developed wings.

[a] A more detailed account is given in Bul. 19, n. s., Div. Ent., pp. 62–67.

CUTWORMS.

These insects are among the most troublesome with which the vegetable grower has to deal, but, although often associated with injury to sugar beet, they as a rule show no preference for this plant. Hence they are of little importance save under exceptional circumstances, when they attack newly planted crops. They are usually present in most gardens and fields, and it is a question of their appearance in numbers and at the time of the year when the plants are just beginning to grow, as to whether they will prove sufficiently destructive to require remedial treatment. They are likely to attack any portion of a beet plant—foliage, flowers, stalks, fruits, or roots—and when they are sufficiently abundant to migrate like army worms they can be quite injurious.

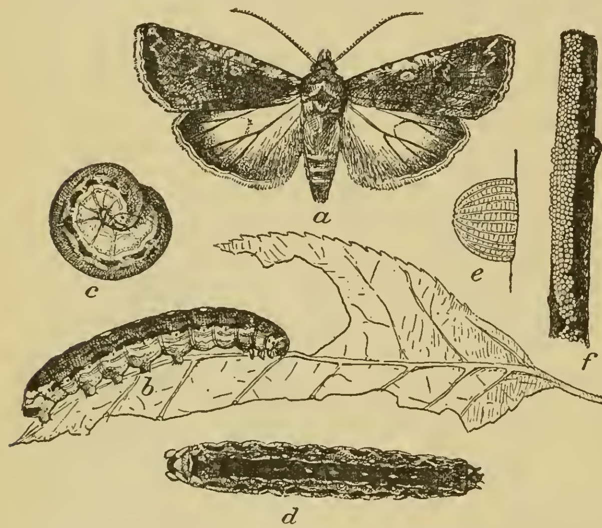

FIG. 25.—*Peridroma margaritosa:* *a*, moth; *b*, normal form of larva, lateral view; *c*, same in curved position; *d*, dark form, dorsal view; *e*, egg from side; *f*, egg mass on twig (after Howard, Division of Entomology).

Although we have two or three score of injurious cutworms, not more than half a dozen of these have been reported to be seriously troublesome to sugar beet. The different species vary considerably as to life and other habits, but in this connection brief mention will be made of only a few of the most important insects of this group.

THE VARIEGATED CUTWORM.

(*Peridroma margaritosa* Haw. [*saucia* Hbn.].)

There is little doubt that this is the most important and widely known of all cutworms. It is cosmopolitan and likely to be found anywhere, and although it favors vegetable crops it is able to eke out an existence on almost any form of vegetation. The progenitor of this cutworm is a rather large grayish-brown moth or "miller," and the full-grown cutworm measures about 1¾ inches. It is variable, like the moth, some forms being pale and others darker. The usual ground color is rather dull brown, mottled with gray and smoky black above, the characteristic feature consisting of a row of four to six yellow medio-dorsal rounded spots. The different stages are shown in figure 25. During the severe outbreak of this species in 1900, already mentioned, practically all forms of vegetables, including sugar and table beets, were attacked, the insect even eating into roots and tubers and devouring the foliage and gnawing the bark of trees.

A detailed account of this species is furnished in Bulletin 29, new series, Division of Entomology.

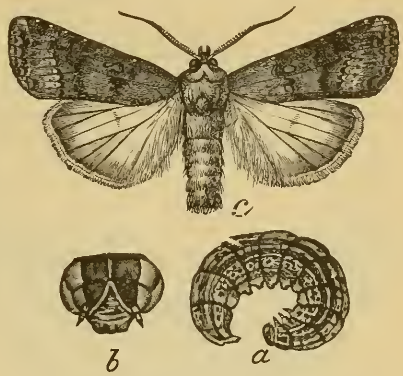

FIG. 26.—*Agrotis ypsilon*, a beet cutworm: *a*, larva; *b*, head of same; *c*, adult—somewhat enlarged (fom Howard, Division of Entomology).

THE GREASY CUTWORM.

(*Agrotis ypsilon* Rott.)

This species is commonly found in fields of beets, and may be selected as typical of its class. In importance as a pest it is perhaps second only to the variegated cutworm. It is of about the same size (fig. 26), and of a dull, dirty brown color, characteristic of most cutworms, with the lower portion paler and greenish, and the entire surface of a greasy appearance, whence the name. It is cosmopolitan, and has a most emphatic and pernicious cutting habit. It is especially troublesome to newly set tomato plants, to potato, corn, lettuce, and tobacco.

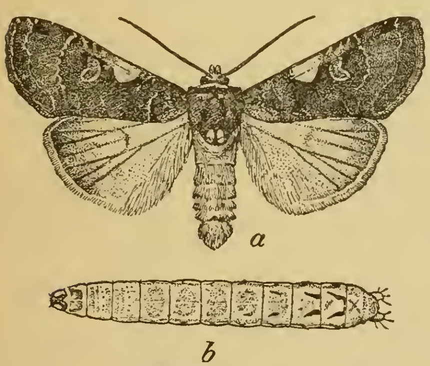

FIG. 27.—*Noctua c-nigrum:* *a*, moth; *b*, larva—somewhat enlarged (author's illustration, Division of Entomology).

THE SPOTTED CUTWORM.

(*Noctua c-nigrum* Linn.)

This is one of our commonest and most destructive species, and is commonly found on beets. It resembles the variegated cutworm in being cosmopolitan, nearly omnivorous, a climbing species, and in migrating in numbers like the army worms. The moth (fig. 27, *a*) has brown forewings, tinged with red or purplish and marked with lighter colors as figured. The cutworm (*b*) is pale brown or gray, sometimes whitish with greenish or olive tints, and has the last segments marked with oblique black lines. It measures, fully extended, about an inch and a half. The principal crops which it has been known to injure include, besides beets, corn, and other cereals, cabbage, cauliflower, turnip, pea, carrot, tomato, celery, rhubarb, currant, gooseberry, clover, violets and some other ornamental plants. It has been noticed attacking grasses and oats, but does not appear to resort to these plants when more choice food is at hand.

THE WESTERN ARMY CUTWORM.

(*Chorizagrotis agrestis* Grote.)

In 1897 this cutworm, which had hitherto led an unpretentious existence in the Missoula Valley, Montana, developed in great numbers, and a serious outbreak followed. According to the account given by Dr. E. V. Wilcox (Bul. 17, Montana Agl. Exp. Sta., 1898), this visitation resembled that of the common army worm, and the list of observed food plants shows that it can be a very serious vegetable pest, since, besides beets, it attacks cabbage, horse-radish, radish, mustard, turnip, pea, tomato, potato, onion, celery, rhubarb, corn, cereals, grasses, clover and other forage crops, forest and fruit trees, and bush fruits.

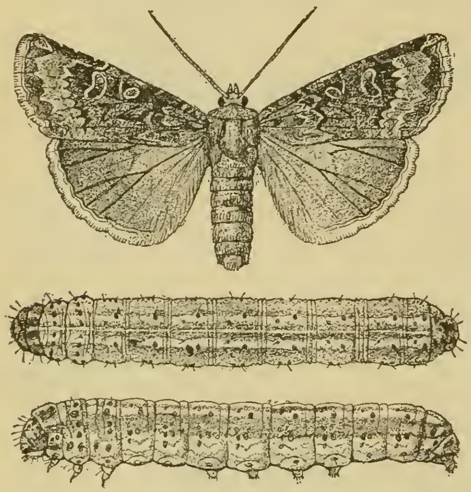

FIG. 28.—*Chorizagrotis agrestis:* moth above; larva, dorsal view, in center; larva, ventral view, below—somewhat enlarged (original, Division of Entomology).

This cutworm (fig. 28) is of the ordinary type, and attains a length of 2 inches when mature. Its body is nearly smooth, only a few short hairs being observable. The color varies from pale green to dark brown. Along the sides there are alternating longitudinal light and dark bands. The moth is brown with gray markings, has a wing expanse of about 1¼ inches, and is quite variable.[a]

The recorded distribution comprises Kansas, Nebraska, Texas, New Mexico, Arizona, Colorado, Montana, and California.

Although the injuries committed in 1897 have not to our knowledge been duplicated, reports have reached us of the occurrence of great numbers of the species in widely separated localities, the moths flying about in such numbers as to become annoying pests in dwellings. Such reports were received from Missouri in 1902, and from Arizona and Colorado in 1903. In Montana a "wild sunflower" (*Balsamorrhiza sagittata*) and avens (*Geum triflorum*) are favorite food plants, but in other localities it seems probable that the natural

[a] This species is so often accompanied by two related forms, more particularly by *Chorizagrotis introferens* Grote, as to give rise to the supposition that all are colorational varieties of the same species, the truth of which will probably be established by rearing from selected females.

food, as with so many other forms of cutworms, consists of wild grasses of little or no value, and when grasses or weeds are replaced by crops these are apt to be attacked, under favoring conditions.

THE COTTON CUTWORM.

(*Prodenia ornithogalli* Guen.)

This species, although called a cutworm, has little in common with preceding species, being more distinctly marked, more or less diurnal in habit, and in having the cutting trait somewhat feebly developed. In fact, it more nearly resembles the boll worm in its habit of boring into the bolls of cotton and the fruit of tomato. It is a very common species, but as a rule not especially destructive, as it is more solitary than the common cutworms. It has been observed attacking and doing more or less injury to beets, potato, asparagus, cabbage, cucumber, peach, and cottonwood. It is also common on violet, morning-glory, and other ornamental plants, and on weeds, and is frequently found in greenhouses.

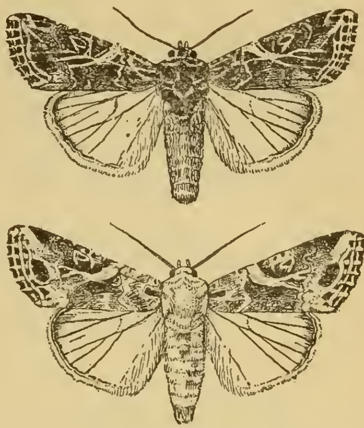

FIG. 29.—*Prodenia ornithogalli:* dark form, male, above; pale form, female, below—somewhat enlarged (original, Division of Entomology).

The moth has a wing expanse of a little less than 1½ inches, and is quite distinct from any which have already been considered, the fore-wings having a more complicated pattern. There is much variation in the colors, which has caused differently colored varieties to be described as species. Two extreme forms are shown in figure 29. That they are mere colorational varieties of one species has been proved by the writer by rearing both from an egg mass deposited by a single female (Bul. 27, new series, Div. Ent., pp. 64–73, 114).

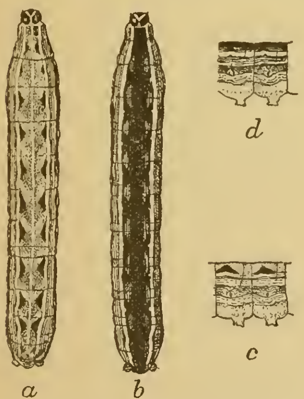

FIG. 30.—*Prodenia ornithogalli: a*, pale form of larva; *b*, dark form of same; *c*, lateral view of abdominal proleg segments of pale form; *d*, same of dark form—all enlarged (original, Division of Entomology).

The larva is subject to the same variation as the moth. The ground color is generally olive or greenish brown, finely lined with dark gray and brown, while the upper surface is ornamented with a double row of velvety black or greenish spots, which give it a striking appearance. A pale form of the larva is shown in figure 30 at *a* and a darker form at *b*. It is a singular fact that in the writer's experiments the pale larva produced the dark form of moth and the dark larva the lighter moth. The distribution of this species is wide, including the territory from Massachusetts to the Gulf, and westward to California, but it occurs in greater numbers southward. In the northern portion of its range it is occasionally killed off by exceedingly cold winter temperatures, as happened in 1899. The larvæ are found abroad from April to November. As with other species which have apparently come northward from the Gulf region, this species is most destructive in the autumn of the year. It is credited with being double-brooded, and possibly three generations are produced in the South. Larvæ have been observed by the writer to complete their development in a month, and the pupal period varies from 12 to 25 days. The winter is evidently passed in the pupal condition, in which respect this species differs from the ordinary cutworm.

THE GREEN BEET LEAF-WORM.

(*Peridroma incivis* Guen.)

In certain years and localities, as in Illinois in 1899 and 1900, this species is more abundant on beet leaves than any other caterpillar. It feeds on both surfaces of a leaf, and has been observed eating purslane, which is doubtless its natural food plant.

The larva, also called green cutworm, is green with a white or pinkish stripe on each side of the body. The species is generally distributed, and quite common in Illinois and Kentucky, where it is apparently double-brooded.

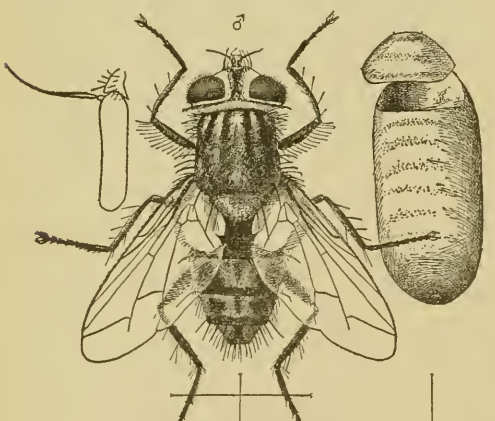

FIG. 31.—*Euphrorcra claripennis*, a common cutworm parasite: adult with puparium at right and enlarged antenna at left (from Howard, Division of Entomology).

NATURAL ENEMIES.

Cutworms are exposed to a great variety of natural enemies, but as a rule these are not efficient checks except when the cutworms appear in great numbers and travel like the army worms. At such times many species of predaceous and parasitic insects and predatory mammals and birds, wild and domestic, destroy them in great numbers. Of the predaceous enemies ground beetles are most abundant, while the parasites include numerous species of ichneumon and tachina flies and a few chalcis flies. A common species of tachina fly is shown in figure 31. Cutworms are also subject to a fungous disease *Empusa aulicæ*. Among birds which are beneficial by feeding upon cutworms are robins, crows, the bluebird, and the bluejay, and among domestic animals are chickens, ducks, turkeys, Guinea fowls, and hogs.

METHODS OF CONTROL.

From what has been said of the utility of domestic fowls and other animals it is obvious that with proper judgment their services would save great losses that it might otherwise be difficult to avert.

Poisoned baits are the standard remedies against cutworms, and to be most effective they should be applied as soon as attack is noticed. They are particularly valuable in cases where the direct application of insecticides to a plant is impossible owing to the danger of poisoning persons or stock when it is used for food. There are two kinds of bait—fresh vegetable and bran mash.

Vegetable bait may be prepared as follows: Spray a patch of clover, pigweed, or some useless succulent plant that grows by the roadside or in fence corners, with Paris green, 1 pound to 150 gallons of water; mow it close to the ground, and place it while fresh in small heaps about the infested plants at intervals of a few feet. The later in the day this can be done the better, as the material keeps fresh longer and the cutworms feed almost exclusively at night. Owing to the wilting of this bait, particularly in dry, sunny weather, it is advisable to cover each heap with a chip, shingle, or bit of bark for its protection against the sun's rays.

Bran mash or bran-arsenic mash is of equal value to a fresh vegetable bait, and, according to some, still more efficacious. Paris green, arsenoid, white arsenic, or in fact any arsenical can be used for poisoning this bait, and in its preparation, on account of the weight of the poison and the fact that it soon sinks to the bottom of the water when stirred, it is best first to mix the bran with water and sugar and then add the poison. The proportions are 2 or 3 ounces of sugar or a similar quantity of glucose or molasses to a gallon of water and a sufficient amount of bran (about a pound per gallon) to make, when stirred, a mixture that will readily run through the fingers.

Before planting a crop it is advisable to employ such bait, and its perfect success is assured by having the ground bare, which practically compels the cutworms to feed upon it.

Bordeaux mixture.—This fungicide has been recently tested against the variegated cutworm upon potato vines and asparagus. It was sprayed on as a remedy for blight, and it was discovered that the plants thus treated were free from attack. The use of this fungicide as a cutworm deterrent is certainly advisable. In any case, it should be used as a diluent for whatever arsenical is used.

Hand methods.—On some plants it is next to impossible to apply any but hand methods with good results. Experiments in Washington State during the season of 1900 demonstrated conclusively that in some cases it required less time to shake or brush cutworms from affected plants than to destroy them by spraying or otherwise.

"*Back firing*," a somewhat old-fashioned practice, is of great use in destroying army worms, cutworms, and other forms of insects when they occur in such numbers as to ruin a crop. It consists in burning a rather wide stretch in advance of the wind at the farthest extremity of the field, and then stamping this out to prevent the fire from reaching other fields beyond. The field is then burned, beginning with the side from which the wind is blowing. This has the effect of destroying the entire field, with all the cutworms and many other insects which it contains, with practically no danger of the fire spreading to fields where it is not desired.

When cutworms assume the habit of traveling in armies they should be treated in the same manner as advised against the army worms.

ARMY WORMS.

In addition to the army cutworm that has been mentioned and the variegated and spotted cutworms, which sometimes exhibit the same migratory tendency, there are three important species of beet-feeding caterpillars, allied to the cutworms, but lacking the true cutworm habit. The most important of these is the beet army worm.

THE BEET ARMY WORM.

(*Caradrina* [*Laphygma*] *exigua* Hbn.)

In the year 1899 this species, which had not previously attracted attention by its ravages, became prominent as an enemy to the sugar beet in Colorado. Subsequent study showed that it had been observed at an earlier date attacking crop and other plants in New Mexico and in California. It is an imported pest, and, although not at the present time of great importance, bids fair, in course of time, to become a serious enemy to the cultivation of sugar beet in America. It has evidently come by way of California and is traveling eastward, a method of migration of which there is precedent in the Colorado potato beetle.

The moth (fig. 32, *a*) is mottled gray, resembling the plain form of the related fall army worm. The fore-wings are broader and paler, and the reniform and other markings are more distinct. The wing expanse is less than an inch and one-half. The larva is rather slender, with a small head, and the body greenish or olivaceous and striped as shown (fig. 32, *b*, *c*, and fig. 33).

When migrating, the beet army worm attacks several forms of vegetation. Sugar beet appears to be the favorite host plant; table beets are also relished, and it feeds quite as well on lambsquarters, pigweed, and saltbush (Atriplex). When numerous, corn, potato, pea, onion, sunflower, and the leaves of apple, mallow, *Nicotiana glauca*, Cleome, plantain, and wild grasses are eaten. In southern California the moths appear in April and until June; caterpillars of the first generation develop as early as the last week of May and a month later in June. In the cooler climate of Colorado and New Mexico larvæ have been noticed about the middle of June, becoming more abundant in August, when the greatest damage is done. From our somewhat incomplete knowledge of this species it appears that it has a spring and late autumn generation in Colorado and New Mexico, and perhaps a third in southern California, and it is evident that the second generation is generally most destructive.[a]

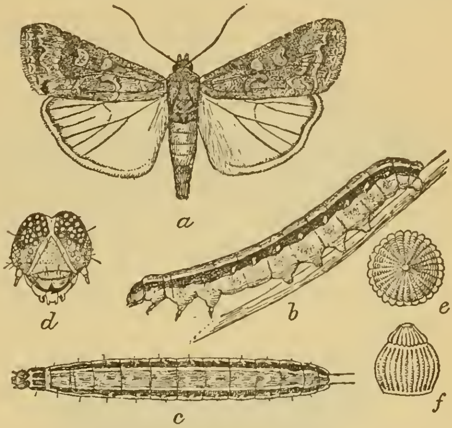

FIG. 32.—*Caradrina exigua:* *a*, moth; *b*, larva, lateral view; *c*, larva, dorsal view; *d*, head of larva; *e*, egg, viewed from above; *f*, egg, from side—all enlarged (*c*,*f*, after Hofmann; *a*-*d*, after Chittenden, Division of Entomology).

Methods of control.—Several remedies have been employed in Colorado with satisfactory results. These include Paris green and kerosene emulsion, both of which killed the insects and checked their numbers for the following year. Paris green was applied as a spray and dry, mixed with flour. With flour it cost about 80 cents an acre. Two sprayings with the liquid preparation were most effectual. When this species is unduly abundant it should be treated in the same manner as the fall army worm (*Laphygma frugiperda* S. & A.), which is quite often associated with injury to sugar beet. The latter attacks nearly all forms of vegetable and other crops, but as it is discussed fully in Bulletin 29, new series, Division of Entomology, further mention is unnecessary here.

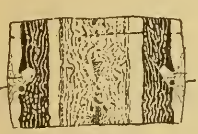

FIG. 33.—*Caradrina exigua:* enlarged section of first proleg segment, dorsal view (original, Division of Entomology).

A third species, the true army worm (*Leucania unipuncta* Haw.), is more strictly an enemy of cereals and grasses, and not, as a rule, of much importance as a beet feeder. Remedies are considered in Circular No. 4, Division of Entomology, and short general accounts of both the true army worm and the fall army worm are furnished in Farmers' Bulletin 132.

WEBWORMS.

Among insects that are nearly always to be found in their natural habitat in fields of beets are two small caterpillars known as webworms. Of these the sugar-beet webworm is a prime beet pest, and the second, known as the garden webworm, is a general feeder, devel-

[a] In a more complete consideration of this species, Bul. 33, new series, Div. Ent., pp. 37–46, references to economic articles by C. P. Gillette and others are furnished.

oping on weeds related to beets and invading cornfields and vegetable gardens when the supply of wild food plants and weeds is scant. Still a third species, the imported cabbage webworm, occasionally occurs on beets, but, as its name indicates, it is a cabbage pest, properly speaking, and does not resort to other plants when Cruciferæ are available.

THE SUGAR-BEET WEBWORM.

(*Loxostege sticticalis* Linn.)[a]

Although primarily a sugar-beet insect, this species, like many others that have been treated, is a periodical pest, and, as it is an introduction from abroad and widening its range, there is likelihood that it will in time assume greater economic importance. It is cousin to the native garden webworm, but the moth is larger, darker colored, and the markings are somewhat more pronounced. With the

FIG. 34.—*Loxostege sticticalis: a*, moth, twice natural size; *b*, larva, less enlarged; *c*, upper surface of first proleg segment of larva; *d*, side view of same; *c*, *d*, more enlarged (reengraved after Insect Life, Division of Entomology).

wings fully expanded it measures nearly an inch and is of a purplish brown color, with darker and paler bands, as shown in figure 34, *a*.

The pale-yellow eggs are laid singly or in rows of two to five or more, overlapping like scales. The young webworms are whitish, with polished black head and piliferous spots. Mature caterpillars (*b*) are darker than the garden webworm, with a preponderance in longitudinal markings.

It is an inhabitant of western and central Europe and northern Asia, and has evidently, like the beet army worm, been introduced from the Orient on the Pacific coast, and is now slowly but steadily pushing its way eastward. In 1869 it came under observation in Utah, and by 1873 had found its way to Missouri. It occurs southward to Kansas and as far north and east as Michigan, but the major portion of reported injuries have occurred in Kansas and Nebraska.

Practically all that is known of the biology of this webworm is from

[a] Riley & Howard, Insect Life, Vol. V, pp. 320–322; Vol. VI, pp. 369–373; Chittenden, Bul. 33, new series, pp. 46–49.

data accumulated by the Department of Agriculture. The life history has not been followed throughout, but two generations have been differentiated, and possibly a third is produced in the most southern region which the insect inhabits, the moths from which issue in autumn. Where observed in Nebraska there was a short-lived July generation, requiring only two weeks between the maturity of the caterpillars and the appearance of the moths, which coupled and deposited eggs for another generation. The caterpillars of the July brood transform to pupæ almost immediately after entering the ground, but the last generation remains as larvæ for some time before assuming the chrysalis stage. A wild food plant, pigweed or careless weed (Amaranthus), has been observed, and it has been noticed also that injury to fields of sugar beet are most observable where the ground had been allowed to run to this wild plant. In Europe it lives on another pigweed (Artemisia). A parasitic enemy of this species is illustrated in figure 35.

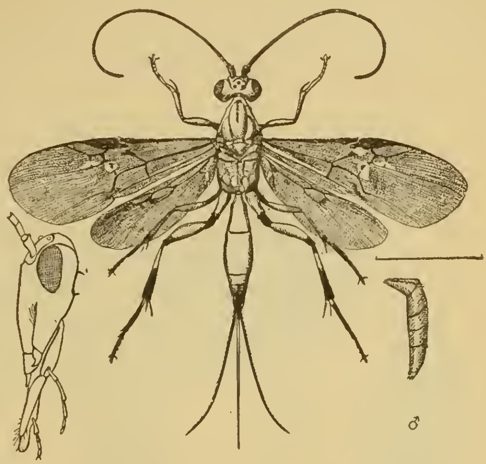

FIG. 35.—*Agathis* (*Cremnops*) *vulgaris:* female, head at left; abdomen of male, side view, at right—enlarged (redrawn after Insect Life, Division of Entomology).

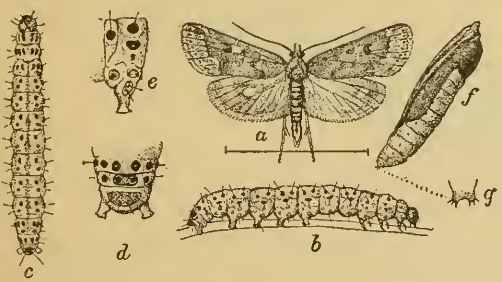

FIG. 36.—*Loxostege similalis:* *a*, male moth; *b*, larva, lateral view; *c*, larva, dorsal view; *d*, anal segment; *e*, abdominal segment, lateral view; *f*, pupa; *g*, cremaster—*a*, *b*, *c*, *f*, somewhat enlarged; *d*, *e*, *g*, more enlarged (reengraved after Riley, except *e*, original, Division of Entomology).

THE GARDEN WEBWORM.

(*Loxostege similalis* Gn.)

The garden webworm has the same natural food plant (Amaranthus) as the sugar-beet species, but is native to America, and although widely distributed is somewhat restricted as regards important injuries to the South and Middle West, particularly in States between the Mississippi Valley and the Rocky Mountain region. In 1885 it was the cause of serious trouble over a large area, including five States and Indian Territory.[a] It is a general feeder, and attacks most vegetables, cereals, grasses and other forage crops, as also tobacco

[a] Rept. Comm. Agr. for 1885 (1886), pp. 265–270.

and sugar-cane, but its injuries are most pronounced on corn and cotton. The moth (fig. 36, *a*) is variable from yellow to buff, and there is variation in the degree of markings of the fore-wings. The expanse is about three-fourths of an inch. The larva (*b*, *c*) is also variable, the ground colors running through pale and greenish yellow to dark yellow. It seems probable that, as two generations have been observed in the Middle States and three in the South, the life history of this species is not materially different from that of the beet webworm. Eggs are deposited on lower surfaces of leaves, and the caterpillar, soon after hatching, draws together the edges of a leaf by means of its web, or fastens together two contiguous leaves, forming a shelter, from which it crawls forth to feed. A parasite of this species is shown in figure 37.

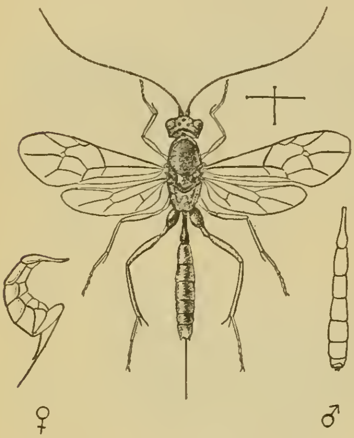

Fig. 37.—*Limnerria curyercontis:* adult female; ♀, abdomen of female, lateral view; ♂, abdomen of male, dorsal view (after Insect Life, Division of Entomology).

Remedies.—Paris green applied as a spray has been used with perfect satisfaction against both of these webworms, the fact that they are more or less surrounded by webs and leaf tissues offering little or no barrier to the effects of the poison. In addition, clean cultural methods, including late plowing in the fall followed by deep plowing in spring, and the burning of all waste material and weeds, are of service in controlling these pests. Early planting is also useful as a safeguard for some crops.

MISCELLANEOUS CATERPILLARS.

In addition to the caterpillars which have been mentioned—cutworms, army worms, and webworms—a number of other forms of different classes and with varying habits are so frequently found in beet fields as to deserve consideration. The first two that will be mentioned are naked caterpillars; the last two are hairy caterpillars, or woolly bears, as they are familiarly termed.

THE WHITE-LINED MORNING SPHINX.

(*Deilephila lineata* Fab.)

An illustration and short account of this species, known also as the purslane sphinx, is presented, because it is frequently found in beet fields and evinces an apparent preference for beet among cultivated plants. From its very large size it might be judged a pest of importance. On the contrary, it feeds naturally on purslane, seeming to injure beets only when the former plant is exhausted or unavailable. Occasionally it occurs in some numbers, as has happened in several localities in the past three years, and then may attack various other useful plants, among which turnip, watermelon, buckwheat, grape, and the leaves of apple have been recorded. During 1900 Mr. Edward C. Post reported injury to sugar beets at Dundee, Mich., and Mr. T. Lytle, Manzanola, Colo., reported damage to tomatoes and to apple and prune trees.

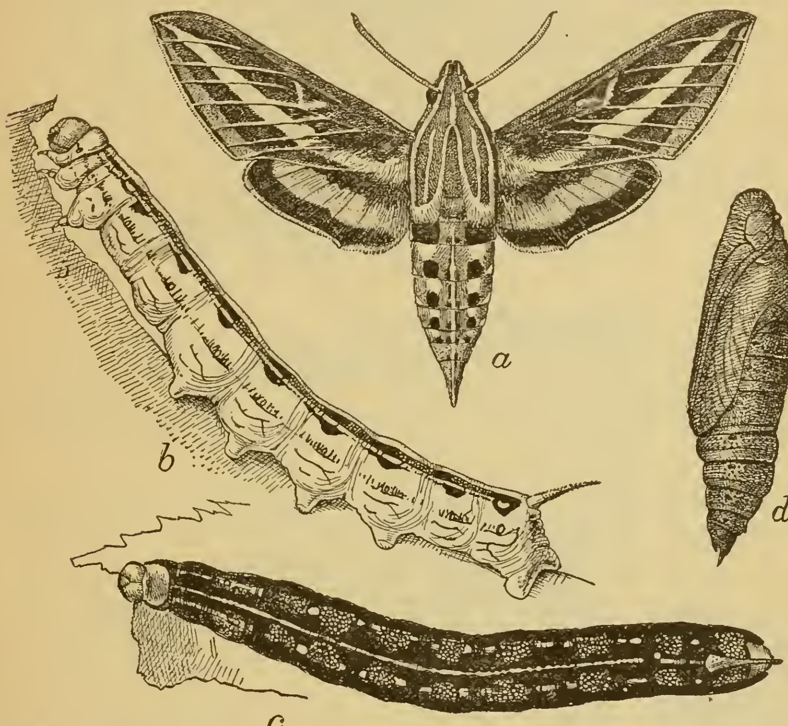

Fig. 38.—*Deilephila lineata:* *a*, moth; *b*, pale larva; *c*, dark form of larva; *d*, pupa—all natural size (original, Division of Entomology).

The resemblance of the adult (fig. 38, *a*) to a humming bird is marked particularly when the insect is in flight. It will be noted that there are two forms of the caterpillar, a light one (*b*) and a dark one (*c*). The insect belongs to the same group as the more familiar tomato and tobacco worms, and its life habits are somewhat similar.

Remedies.—On account of the large size of this insect it is not difficult to control it by picking the young caterpillars from the plants and destroying them. They also succumb to the arsenicals.

THE ZEBRA CATERPILLAR.

(*Mamestra picta* Harr.)

The zebra caterpillar is a conspicuous garden pest, particularly attached to vegetables, showing some preference for beets and spinach,

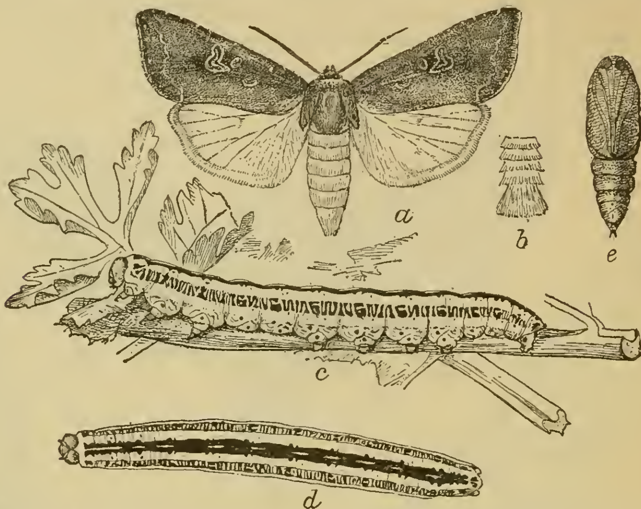

FIG. 39.—*Mamestra picta*: *a*, female moth; *b*, abdominal segments of male moth; *c*, pale form of larva, lateral view; *d*, larva, dorsal view; *c*, pupa—all somewhat enlarged (original, Division of Entomology).

cabbage, celery, peas, and asparagus, and feeding at times on nearly all forms of vegetation, including cereals, weeds, and the foliage of trees. As previously mentioned, it bears the distinction of being the first insect reported to affect beets in this country. The moth (fig. 39, *a*) resembles in general contour the progenitors of cutworms belonging to the same group of insects. It has a wing expanse of about an inch and a half; the fore-wings and thorax are brown, shaded with darker purplish brown, and the hind-wings are white, tipped with pale brown at the margins. The larva or caterpillar (fig. 39, *c*, *d*) is somewhat variable, but the head is red and the ground color yellow, more or less strongly marked with black, the stripes on the sides suggesting the name of zebra caterpillar. The larva when first hatched from the egg is dull gray and looks quite unlike the mature form. Two views of the newly hatched larva are presented in figure 40, *a*, *b*, while the third stage is shown at *c*.

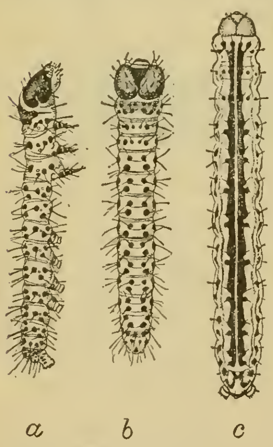

FIG. 40.—*Mamestra picta*: *a*, *b*, newly hatched larva; *c*, larva of third stage—much enlarged (original, Division of Entomology).

This species is quite abundant in the North, becoming most troublesome in the second generation, which usually appears in September. In addition to the plants that have been mentioned as furnishing food for the zebra caterpillar are cauliflower, turnip, beans, carrot, potato, corn, currant, cranberry, willow, roses, and others. The winter is passed in the pupal condition, and the moths appear in May and June. The first eggs hatch in a moderate temperature in six days, and the larval period is about five weeks. The pupal period is very long, lasting, as observed by the writer, sixty-seven days, making in all a period of one hundred and ten days from the time the eggs were laid until the moths appeared, late in August. This species can endure a considerable amount of cold, but is very susceptible to parasitic attack, and to a less extent to fungous diseases.

Methods of control.—The caterpillars when first hatched are gregarious, hence easily discovered at this time and destroyed by hand or by poisons. They yield readily to sprays of arsenicals, but these are not necessary in ordinary cases of attack.

THE SALT-MARSH CATERPILLAR.

(*Leucarctia acræa* Dru.)

Several forms of hairy caterpillars, such as the yellow bear (*Spilosoma virginica*), of similar appearance and habits, are commonly found on sugar beet. One of these, known as the salt-marsh caterpillar

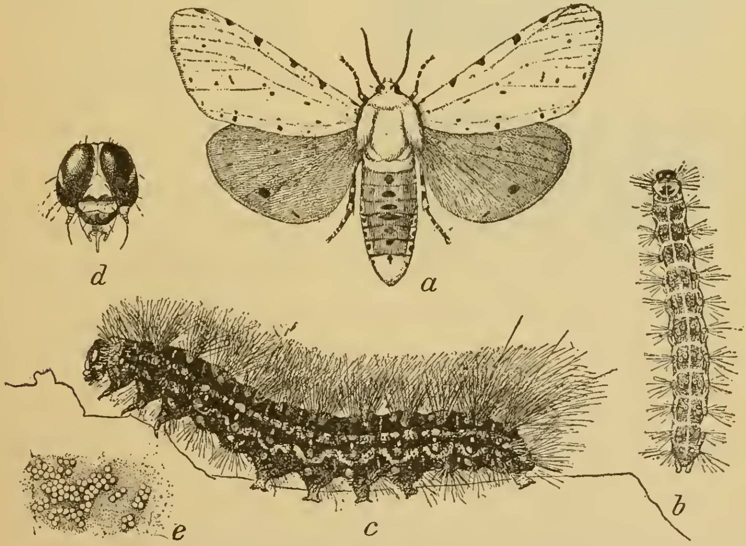

FIG. 41.—*Leucarctia acræa:* *a*, female moth; *b*, half-grown larva; *c*, mature larva, lateral view; *d*, head of same, front view; *e*, egg mass—all slightly enlarged except *d*, more enlarged (original, Division of Entomology).

(*Leucarctia acræa* Dru.), from its ravages early in the past century upon forage crops grown in the salt marshes of New England, is occasionally troublesome in beet and corn fields and in gardens.

This caterpillar differs from the common yellow bear in having a darker body, and the sides are distinctly ornamented with yellow markings. The two species are of about the same length, and the hairs present a similar variation in color. A young larva is illustrated at figure 41, *b*, a mature one at *c*. The moths also closely resemble each other, but the fore-wings of the present species are strongly marked with black, and the abdomen, with exception of the first and last segments, is bright ocher above, with black markings. In the female the hind-wings are white, like the fore-wings, and similarly marked with black, but in the male they are ocher with two black dots (fig. 41, *a*). The life economy of these species is very similar; they form the same sorts of cocoons and transform in any convenient place where shelter can be obtained. In New England the salt-marsh caterpillar is credited with having a single generation, but a little farther south, in the Middle States, two generations have been recognized.

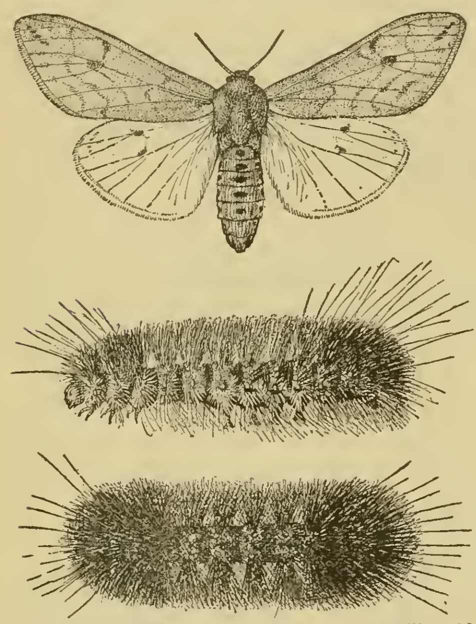

FIG. 42.—*Isia isabella:* male moth above; caterpillar, side view, in middle; dorsal view at bottom—somewhat enlarged (original, Division of Entomology).

THE HEDGEHOG CATERPILLAR.

(*Isia* [*Pyrrharctia*] *isabella* S. & A.)

Another conspicuous caterpillar known to attack beets is shown in the accompanying illustration (fig. 42). It is recorded also as affecting peas and corn, but appears to prefer plantain and other weeds, such as dandelion and burdock. The general color of this caterpillar is bright cinnamon red and usually each end is black. The long hairs with which the body is covered are so evenly distributed as to give it the appearance of being shorn or cropped. The name of hedgehog caterpillar is derived from the habit of this insect of rolling up when disturbed and of passing the winter under the bark of trees or in some similar location rolled up like a hedgehog. The life history of this insect is very similar to that of the preceding. The moth (fig. 42) is dull orange, with the fore-wings marked with dusky stripes, both the fore and hind-wings being spotted with black, the latter a little paler than the others.

Remedies.—As a rule neither this insect nor the salt-marsh caterpillar occurs in troublesome numbers; hence remedies are not often necessary. It can be controlled by ordinary methods of spraying and hand picking.

GRASSHOPPERS, CRICKETS, AND RELATED INSECTS.

Of great economic importance in the West, and in some seasons in other regions, are numerous species of locusts, popularly termed grasshoppers. Several forms of related insects, such as katydids and crickets, are also injurious, but all of these insects are general feeders, and as a rule destructive to sugar beets and other vegetable crops only in seasons which have been particularly favorable to their multiplication, and their operations are mainly confined to fields adjacent to grass lands. The numbers of these insects mount into the hundreds, but the really important species might be reduced to between twenty and thirty. Fourteen are listed as sugar-beet pests.

For present purposes it will be necessary to mention specifically only a few of the most abundant of the grasshoppers. Like most other forms of the order Orthoptera, they are mostly large insects, with mouth parts formed for biting, and with incomplete metamorphoses, the young more or less closely resembling the adults, save for the lack of wings. Their name is sufficient indication of their habits: They live normally on grasses for the most part, and their thighs are large, fitting them for long leaps. Everyone knows them so well that further description is unnecessary. Some species are capable of extended flight for hundreds of miles, with occasional intermissions daily for food. In their migrations they go in swarms, and sometimes darken the face of the sun, or at night of the moon.

Grasshoppers may be classified, as regards their habits, as nonmigratory and migratory. The former breed and pass their entire lives in or near the place where the eggs were laid. The migratory species breed in enormous numbers, and when they become too abundant for the limited food supply of a region, they develop the migrating habit and travel in swarms. These insects are particularly abundant and troublesome in arid and semidesert regions, and as their numbers are subject to great variation according to climatic and other conditions, the visitation of a locust swarm may be expected at any time during the warmer months of the year. In dry regions locusts are the most dreaded of insect pests. Because of their voracity and the rapidity of their attack, they lay waste entire townships, counties, and even large portions of States.

THE RED-LEGGED LOCUST.

(*Melanoplus femur-rubrum* De G.).

This is our commonest North American grasshopper, being found practically everywhere. It is one of the smaller species (fig. 43), and where it is not held in subjection by numerous natural enemies of various kinds it may become a decided nuisance in cultivated lands. It was destructive to sugar beet in Illinois in 1899. It seldom exhibits the migratory tendency, but sometimes gathers in swarms and moves in concert, not, however, rising to great heights, but drifting with the wind as do the true migratory species.

FIG. 43.—*Melanoplus femur-rubrum*—natural size (after Riley).

THE ROCKY MOUNTAIN LOCUST.

(*Melanoplus spretus* Thomas).

This is the most destructive of all native grasshoppers, and has been the cause of greater losses to agriculture in the past thirty years or more than perhaps all of the other known species of grasshoppers combined. Its range of injuriousness is not limited to the Rocky Mountain region, but it is more abundant there than elsewhere. It is illustrated in figures 44 and 45.

Those who were interested in farming in the 70's in Kansas, Nebraska, and some neighboring States have cause to remember the depredations of the Rocky Mountain locust. During 1874–1877 it was directly responsible for the loss of $100,000,000, in addition to an indirect loss by the stoppage of business and other enterprises which might have aggregated as much more. It was for an investigation of this species that the

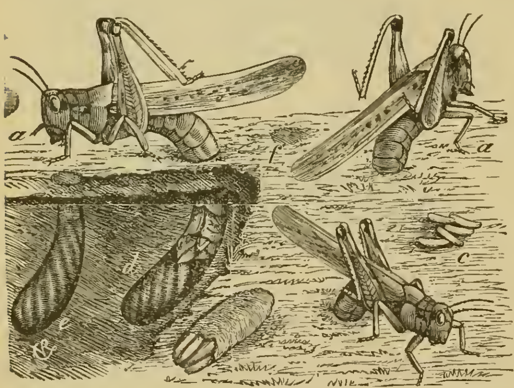

FIG. 44.—*Melanoplus spretus*: *a*, *a*, *a*, female in different positions, ovipositing; *b*, egg-pod extracted from ground, with the end broken open; *c*, a few eggs lying loose on the ground; *d*, *e*, show the earth partially removed, to illustrate an egg-mass already in place and one being placed; *f*, shows where such a mass has been covered up (after Riley).

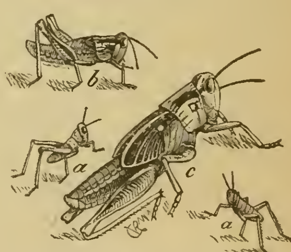

FIG. 45.—*Melanoplus spretus*: *a*, *a*, newly hatched nymph; *b*, full-grown nymph; *c*, pupa, natural size (after Riley).

United States Entomological Commission was formed, which published from 1877 to 1879 two voluminous reports on it alone. A shorter account of this and some of the other more important grasshoppers discussed in the Commission Reports is furnished in Bulletin No. 25 (o. s.), Division of Entomology.

THE DIFFERENTIAL LOCUST.

(*Melanoplus differentialis* Thomas.)

In Kansas and Nebraska and elsewhere in the Middle West the farmer is much bothered at times by the large yellow locust, shown in figure 46. It can usually be found along roadsides and on the edges of groves, preferring rank vegetation where such abounds. When it becomes unusually numerous it is quite destructive to vegetable crops and to cereals; in fact, it is rated by some as next in importance to the two species which have been considered. Two forms of this insect make their home in the Middle West—a yellow form, which is the commonest, and a black one. They do not appear to differ otherwise than in color.

FIG. 46.—*Melanoplus differentialis*, natural size (after Riley).

THE TWO-STRIPED LOCUST.

(*Melanoplus bivittatus* Say.)

The name two-striped locust and the accompanying illustration (fig. 47) together with the statement that the ground color of this species is brown, striped with yellow, is sufficient for its determination. It is somewhat variable, however. Like others of its kind it develops where vegetation is rank, in weed patches and in low ground, and after exhausting the vegetation in such localities it enters gardens and cornfields and does much injury to crops. It occurs from the Atlantic to the Pacific, and from the Gulf States to far North.

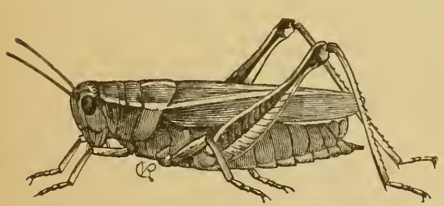

FIG. 47.—*Melanoplus bivittatus*, natural size (after Riley).

METHODS OF CONTROL.

Grasshoppers are generally kept within normal numbers by numerous natural agencies, among which are nearly all large forms of insectivorous birds and mammals, batrachians and reptiles, and fungous diseases. They also have large numbers of predaceous and parasitic insect enemies, which kill them off in ordinary seasons. With changes of atmospheric conditions, however, the insect and fungous enemies are frequently destroyed, and then the grasshoppers increase in abundance. In such cases they can be destroyed by several artificial methods. The remedies that have proved most efficient are: (1) plowing under the eggs before these have had time to hatch, and

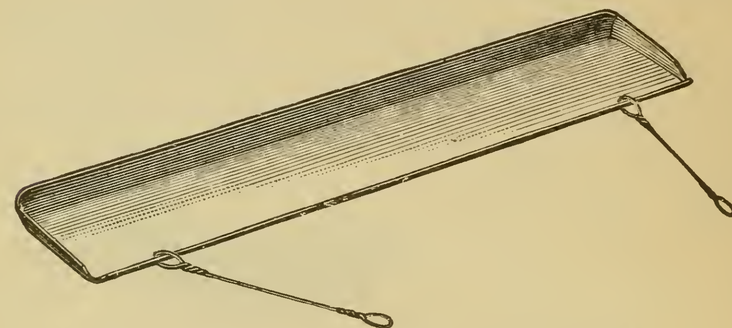

FIG. 48.—A simple coal-tar pan to be drawn by hand (after Riley).

(2) capturing the unfledged locusts, as well as many of those which have become winged, by means of hopperdozers or kerosene pans.

Hopperdozers are necessary implements of warfare against most grasshoppers. They are shallow sheet-iron pans, made of any size most convenient, or canvas frames, mounted on runners to be drawn over the ground either by a horse or by hand, preferably against the wind, in such a manner that the grasshoppers will leap into them and be killed by coming into contact with the tar or oil which is poured into them for the purpose. Two forms of hopperdozers are shown in figures 48 and 49.

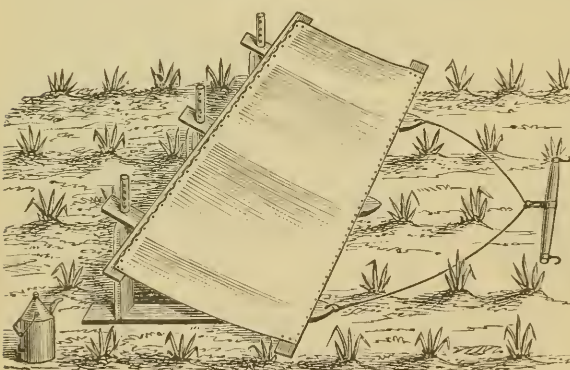

FIG. 49.—A canvas hopperdozer to be drawn by horse (after Riley).

Bran-arsenic mixture is another remedy of great value in the prevention of injury to our cultivated crops. The directions for preparing this mash have been given under remedies for cutworms (page 185).

Fungous diseases as a remedy.—During the years 1901–2 the subject of the possible control of grasshoppers by means of contagious diseases was taken up by the Division of Entomology, and a report by Dr.

Howard of progress in experimental work was published in the Yearbook of the Department for 1901 (pp. 459–470). Unfortunately the spread of these diseases is so contingent upon certain weather conditions that while uninfected grasshoppers may be inoculated under the most favorable circumstances, we can not always obtain or predict atmospheric conditions which will operate with the disease in destroying the grasshoppers. The conclusion is therefore reached that, owing to the inability of man to control the conditions necessary to the spreading of the disease, it is far better to employ the bran-arsenic mash, hopperdozers, fall plowing, and other remedies which have been specified where possible in preference to the fungus; in other words, we can not depend absolutely on the fungus, although in some cases it is eminently beneficial, more especially in climates which are unusually moist and in which the conditions desired are ordinarily present. The principal diseases in question are caused by *Mucor ramosus*, *Empusa grylli*, and an undetermined species of the genus Sporotrichum.

Poisoned horse droppings.—During recent years Mr. Norman Criddle has used a mixture with great success against locusts in Manitoba. It consists of 1 part of Paris green mixed thoroughly in 60 parts of fresh horse droppings, 2 pounds of salt to half a barrel of mixture being added after being dissolved in water. This is placed in a half barrel and drawn on a cart to the edge of the infested field or one likely to be invaded. The mixture is then scattered broadcast along the edge of the crop, or wherever needed, by means of a trowel or wooden paddle. The locusts are attracted to it and are killed in large numbers by eating the poison.[a] Although this mixture is "sure death," it sometimes requires from two to five days for it to kill the locusts.

Rye as a trap crop.—Manitoba farmers also deal successfully with locusts by sowing a strip of rye around the edge of a field of wheat. The former grain grows more rapidly and it requires a long time for the insects to eat sufficiently of it to destroy it. The rye is poisoned with a spray of Paris green. Beet fields might be protected in the same manner.

Burning over and plowing.—In some cases it has been possible to ascertain the particular breeding places of grasshoppers, some species depositing their eggs in pasture lands and among foothills at the bases of mountains in the far West in regions in which the tar weed grows. Here the egg cases can be destroyed by burning over the ground late in the fall after all of the eggs are deposited, or by plowing them in to a depth of 6 or 8 inches before they hatch in the spring.

In case, for any reason, it is not feasible to employ any of these last-mentioned remedies, and the place of egg deposit is ascertained, a watch should be kept for the young grasshoppers and they should be

[a] Fletcher, Rept. Ent. and Bot. Experimental Farms, Canada, for 1902, 1903, p. 187.

destroyed as soon as possible after hatching by means of the bran-arsenic mash.

Turkeys.—Prof. Lawrence Bruner, of Nebraska, states that turkeys are useful in freeing orchards and vineyards of grasshoppers and they may be employed in other fields for the same purpose. In one case a flock of 766 turkeys was kept at work in the destruction of grasshoppers. The turkeys have to be watched, however, as they sometimes vary their diet with vegetables.

Cooperation is of the greatest value in the treatment of grasshoppers, particularly in regions where they reach their greatest development; and the thoroughness with which work is done in one year will show in the greatly reduced numbers with which the farmers will have to deal the next season.

Many of the remedies that have been advised as remedies for grasshoppers in general are applicable to the migratory forms, but these frequently occur in such immense swarms that it is practically impossible to check them until the crops are destroyed. It is of the highest importance, therefore, that remedies be employed at the very first onset, and that these measures be generally observed over considerable territory, as the insects fly rapidly from one field to another.

LEAF-MINERS.

Three forms of maggots, the young of small two-winged flies, more or less resembling the common house fly, mine the leaves of beets and spinach, causing variable blotches on the outer cuticle, which is left entire until ruptured by the escape of the maggot when it matures and deserts its old home for transformation in the earth below. The abandoned mines dry, shrivel, and become torn by subsequent growth of the plant.

THE BEET OR SPINACH LEAF-MINER.

(*Pegomya vicina* Lintn.).[a]

The beet or spinach leaf-miner is the best known of these insects, and at the present time the only one that need be considered. It is practically confined to beets, spinach, and like plants, such as lambs-quarters, and is to be reckoned among prominent beet pests, as it is apparently increasing in destructiveness.

The parent fly is shown at figure 50, *a*, *b* representing the head of the male, and *c* that of the female. The ground color is gray with the front of the head silver white. The body, including the legs, is rather

[a] Lintner, 1st Annual Rept. Insects N. Y. for 1881 (1882), pp. 203–211; Howard, Insect Life, Vol. VII, pp. 379–381; Sirrine, 14th Rept. N. Y. Agricultural Experiment Station for 1895 (1896), pp. 625–633; Pettit, Bul. 175, Mich. State Agr. College Exp. ta., 1899, pp. 356–357.

sparsely covered with long stiff black hairs. When in action the body is carried usually in a somewhat curved position, but when extended measures nearly a quarter of an inch. The maggot (*f*) is white, and so nearly transparent that the contents of the abdomen can be seen through the posterior portion.

In many cases infestation can be traced directly to the insects having bred in lambs-quarters and similar weeds, which if not destroyed by ordinary methods of cultivation mature and die during October. The flies, by close observation, may be seen in flight just above the ground or hovering about their different food plants. The eggs are placed on the lower surface of the leaves and arranged in masses of from two to five. When the young hatch they bury themselves

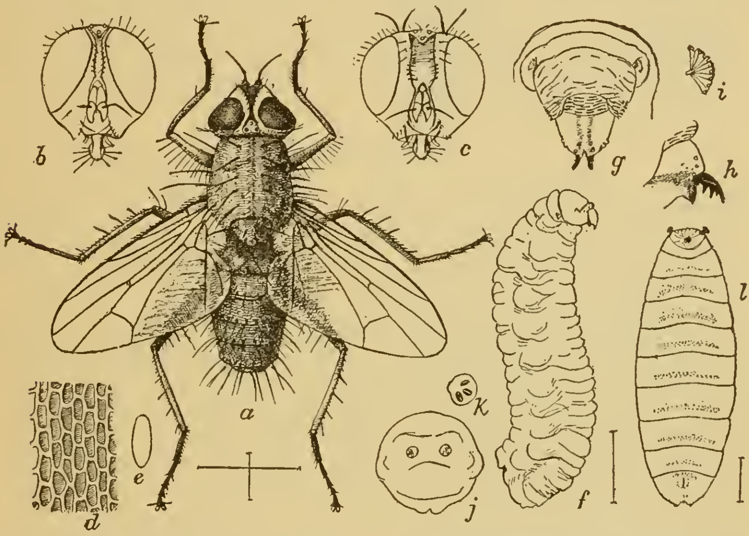

FIG. 50.—*Pegomya vicina:* *a*, fly; *b*, head of male fly; *c*, head of female; *d*, surface of egg, highly magnified; *e*, egg; *f*, maggot; *g*, head of same; *h*, cephalic hooks of maggot; *i*, prothoracic spiracles; *j*, anal segment; *k*, anal spiracles; *l*, puparium—all enlarged (after Howard, Division of Entomology).

within the leaf tissue, constructing a thread-like mine which they afterwards extend in a curve or semicircle.

Transformation to pupæ takes place in most cases in loose soil, which the maggots enter only to a short distance or under fallen leaves. Occasionally maggots transform within a leaf if the latter happens to rest on the ground.

Injury appears to be most frequent in late fall, but may be due to earlier generations in midsummer. Dr. Howard states that eggs hatch in from three to four days, and the larval stage is passed in seven or eight days, the puparium or resting stage requiring from ten to twenty days. These periods will vary according to the state of the atmosphere. An instance of damage to spinach in Pennsylvania was reported in May, 1903.

Methods of control.—When this leaf-miner occurs in kitchen gardens it is most easily controlled by gathering and destroying the leaves as soon as found infested, and neighboring plants which serve it for food should be treated in the same manner. In large fields of sugar beet much injury might be averted by proceeding in the same manner at the outset of attack.

Insecticides have been suggested, but the habit of the maggot of feeding within the leaf at once indicates their uselessness. Kerosene emulsion has been tried without effect. Mr. Sirrine has observed that many gardeners and farmers on Long Island, where this insect is a spinach pest of importance, have practiced late fall and early spring plowing, and are still troubled with it. But it is probable that clean culture is not also practiced, hence the insects have an opportunity to breed in weeds and return to cultivated plants. As the insect appears to prefer spinach to beets, it is possible that the former might be used as a trap crop in sugar-beet fields.

PLANT-BUGS.

The sugar beet furnishes sustenance for hordes of sucking insects, such as plant-bugs, plant-lice, leaf-hoppers, root-lice, and numerous related forms, but many of these insects live normally on wild plants, weeds, and grasses, on which their younger stages are passed, and prefer most other vegetable crops, when readily obtainable, to beets. Among the more common forms of these insects which obtain nourishment by suction are several species of true bugs of the family Capsidæ, generally termed plant-bugs, although some forms are also known as leaf-bugs, chinch bugs, and by similar names indicative of their habits or appearance. The commonest and most injurious of these insects are two forms of false chinch bugs and the tarnished plant-bug and garden flea-hopper.

THE TARNISHED PLANT-BUG.

(*Lygus pratensis* Linn.)

As this is the commonest of all bugs, and, according to general verdict, one of the most troublesome, it may serve as an example of this class. It is at home practically everywhere in North America, from Canada to Mexico, and attacks most plants whether cultivated or wild. It occurs in fields of sugar beet throughout the warm season, and frequently does damage to garden crops, both vegetable and fruit, and to trees grown in nurseries.

The mature plant-bug is of the appearance shown in figure 51 at the left. The general color is a pale, obscure, grayish brown, marked with black and yellow, the thorax also with red. The pattern is variable, but more or less as illustrated. The legs are still paler brown or yellowish, ringed with darker brown. The length is about one-fifth or three-sixteenths of an inch.

This plant-bug has been stated to pass through four stages of growth from the time it hatches from the egg until it reaches the adult condition, but there is little doubt that there are five stages, to agree with other species of plant-bugs which have been traced through their metamorphoses. In the first stage the insect measures only one-twentieth of an inch, and is yellowish or yellowish green in color. The known stages are shown in figures 51 and 52.

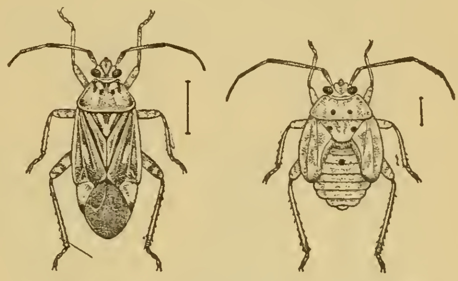

FIG. 51.—*Lygus pratensis:* adult bug at left; last stage of nymph at right—nearly four times natural size (original, Division of Entomology).

Were it not for the fact that this plant-bug feeds upon such a variety of crops as well as weeds, thus diminishing the damage, it would be much more injurious than it really is. It has been asserted, and with probable truth, that the puncture of the bugs is poisonous to plant life.

The bugs are extremely active, and quick of flight as well as on foot, and when disturbed in the least have the habit, in common with many other plant-bugs, of dodging to opposite sides of the plant, where they remain out of sight.

The tarnished plant-bug, as previously stated, can be found afield throughout the season, appearing in early spring and disappearing only when cold weather approaches. Hibernation is usually in the adult stage, but the nymphs or immature forms are sometimes seen under circumstances that would lead to the belief that the species also winters over in this stage. The insects pass the winter under any convenient shelter, particularly in rubbish left in fields and in fence corners, and under leaves, boards, and stones. After copulation in early spring the females deposit their eggs singly and directly on their host plants, oviposition continuing for two weeks or longer.

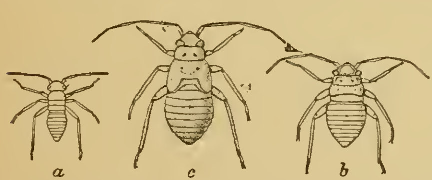

FIG. 52.—*Lygus pratensis:* *a*, newly hatched nymph; *b*, nymph of a later stage; *c*, fourth stage—three or four times natural size (after Forbes, Division of Entomology).

Remedies.—The great activity of the tarnished plant-bug, coupled with its habit of feeding on so great a variety of plants, passing from one to another with no apparent choice, renders it more difficult of control than if it were concentrated. It can not be kept in bounds by any single remedy, at least when it occurs in great numbers. In the application of insecticides, or other remedial measures, it is necessary to include other food plants or most forms of vegetation in order to keep the insects away from the crop which is being injured.

Kerosene emulsion is one of the best remedies, but must be applied thoroughly and at frequent intervals.

Pyrethrum must be applied in the same manner, but as it is one of the most expensive of insecticides its use would hardly be profitable on beets, although valuable on some other plants subject to injury, for example, on berries, where it is impossible to apply poisons that would be harmful to man.

If insecticides are employed they are best applied early in the morning, before the insects have become thoroughly active and while the dew is on the plants, as this facilitates the spreading of most applications which are used.

Hand methods, although scarcely applicable to large fields, are of the greatest value over small areas, and a hand net of stout cloth is useful for sweeping plants and surrounding grasses and weedy vegetation in which the insect is sure to be found. A day's experience will be sufficient to teach anyone that more insects can be captured in this manner than in any other.

Clean culture, although mentioned last, is the first necessity, and if fields subject to injury by this plant-bug are kept free from weeds of all kinds and the rubbish is cleaned away as soon as the crop is harvested, losses will be greatly lessened. After a crop is off "burning over" or "back firing" should be practiced in the same manner as already described in connection with army worms and cutworms.

THE FALSE CHINCH BUG.

(*Nysius angustatus* Uhl.)

This plant-bug is a beet feeder of long standing, and like many other species which have been mentioned, shows a tendency toward being omnivorous, although cruciferous plants, such as cabbage and turnip, appear to be the favorite food. It does more or less injury to potato, lettuce, grapevine, strawberry, and even grass and the foliage of apple trees. Its English cognomen is derived from the fact that since very early times it has been sent by correspondents to official entomologists under the impression that it was the true chinch bug, to which, indeed, it is related.

It is grayish brown and of the appearance shown at figure 53, *c*, measuring about one-eighth of an inch. In the same figure, at *a*, a leaf of potato is illustrated, which shows minute circular specks which are rusty in color where the beak of the bug has been inserted. This recalls the method of attack of certain flea-beetles which have already been described. When occurring in large numbers the false chinch bugs crowd together on plants after the manner of chinch bugs on corn, and harlequin bugs on cabbage, and as they feed by suction they soon exhaust a plant by depriving it of its vital juices, causing it in time to wilt and perish. The distribution of the species extends from New Hampshire to the Gulf, and westward to the Pacific States. It is subject to the same atmospheric influences as the true chinch bug, damp, rainy weather being unfavorable to its development.

Remedies.—The best manner of holding this bug in control consists in clean culture, keeping down all purslane, a favorite host plant, the careful cleaning up of crop remnants and other trash before winter, and the collection of the bugs when they occur in numbers in pans or pails filled with water and a thin scum of kerosene. The free use of kerosene emulsion and pyrethrum is also of value, the latter, though expensive, being efficient in small fields.

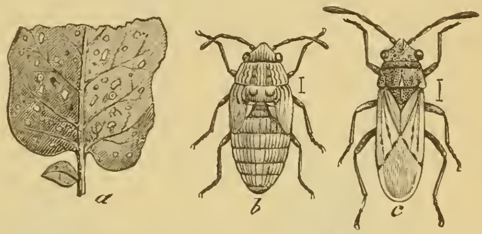

FIG. 53.—*Nysius angustatus*: *a*, part of small leaf of potato, showing punctures of the bug; *b*, last stage of nymph; *c*, adult—*a*, natural size; *b*, *c*, much enlarged (after Riley, Division of Entomology).

THE MINUTE FALSE CHINCH BUG.

(*Nysius minutus* Uhl.)

According to recent reports emanating from several sources in Colorado, this insect is of growing importance as a beet pest. It appears to be more particularly destructive to beets grown for seed, the injury being accomplished by the bugs sapping the green seed, which in consequence dries up and fails to mature properly.

It differs but slightly from the previously mentioned species, being a little smaller, measuring only about a sixteenth of an inch in length. Its distribution and its food habits appear to be practically the same, in fact additional study is necessary to determine whether the two forms are actually distinct species.

Remedies.—It has been ascertained by beet growers that the flooding of infested fields causes the insects to leave, and the growing of mustard as a trap crop has given excellent results, precautions being taken that the mustard be not allowed to run to seed, as it is likely to become a pest itself. Other remedies advised for the common false chinch bug just considered are also applicable.

THE GARDEN FLEA-HOPPER.

(*Halticus uhleri* Giard.)

In recent years this minute black bug has been the occasion of considerable injury in various parts of the country. In 1890 it did damage to beans in Kansas, and in 1896 like injury was inflicted on red clover and other plants in Ohio. It is commonly seen in beet fields, but evinces a partiality for leguminous plants, including cowpea and pea, and has also been destructive to smilax in greenhouses and to potato, morning-glory, and chrysanthemum. In 1897 it was somewhat troublesome on edible legumes in Maryland. Among other plants which it attacks are egg-plant, pumpkin, cabbage, and numerous weeds. It occurs most abundantly on the under side of leaves, which it punctures so as to cause the death of the tissue in small, irregular, somewhat characteristic white patches.

This species is shown highly magnified in fig. 54 in the three forms of its adult stage. In its brachypterous or short-winged form it greatly resembles the common black cucumber flea-beetle, alike in appearance, in the nature of its work, and in its saltatory power. It is evidently native and well distributed from Canada and New England southward to Florida and westward to Utah. This shows a range

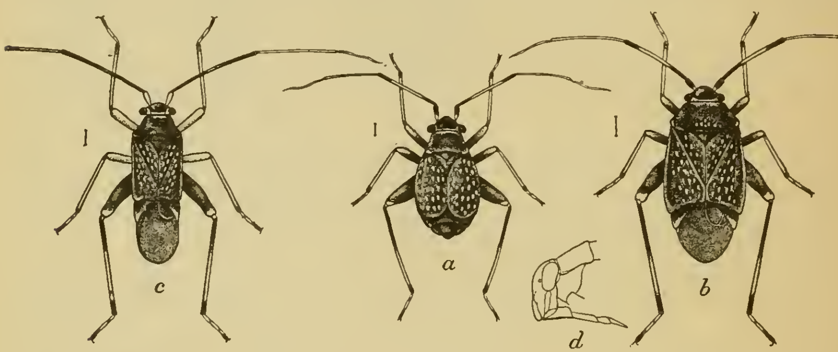

FIG. 54.—*Halticus uhleri: a*, brachypterous female; *b*, full-winged female; *c*, male; *d*, head of male in outline—*a, b, c*, much enlarged; *d*, more enlarged (author's illustration, Division of Entomology).

from the Boreal life zone to the Gulf strip of the Lower Austral. According to the observations of Mr. F. M. Webster, this species may hibernate in the adult stage, although probably it usually passes the winter in the egg.

Remedies.—The best remedy is kerosene emulsion applied thoroughly as an underspray.

Many of the instances of injury that have been reported have been largely due to the planting of susceptible crops in the immediate vicinity of clover, which is evidently the preferred host plant. When the clover is cut the flea-hoppers migrate to other crops, and when sufficiently numerous cause damage. It is obvious that with a little care in cropping, such as the avoidance of growing crops subject to injury in the immediate vicinity of clover, much injury would be averted.

LEAF-HOPPERS.

Numerous species of leaf-hoppers, insects which obtain their food by suction in the same manner as plant-lice, are nearly always to be found on sugar beet and similar vegetables. None of these, however, appears to be restricted to vegetables for food, but usually develop on grasses, although occasionally also on other plants. As a rule, in their earlier stages they exhibit a decided limitation to the food plant on which they began breeding; but as they near the more mature stages they assume the habit of feeding more indiscriminately. Considerable divergence is exhibited in regard to life histories; but since these insects are, as a rule, not particularly destructive to beets, further discussion of this general problem may be omitted.

THE CURRANT LEAF-HOPPER.

(*Empoasca mali* Le B.)

This leaf-hopper is described by Messrs. Forbes and Hart as "probably our worst all-round leaf-hopper pest, so excessively abundant that notwithstanding its varied diet it is able to make a serious attack on quite a number of the cultivated plants on its list." It has been found in extreme abundance on sugar beet everywhere in Illinois, both as nymph and adult, showing its ability to breed on this plant. It also attacks beans, cowpea, potato, celery, and corn, and various fruits, as well as shade and forest trees. It is a tiny insect, pale green in all stages, and is apt to be confused with related species. The row of six (sometimes eight) white dots along the anterior margin of the prothorax distinguishes it from others.

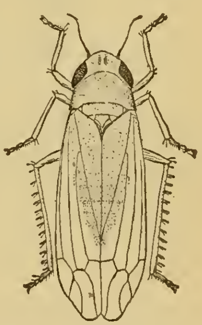

FIG. 55.—*Empoasca flavescens*—highly magnified (original, Division of Entomology).

THE FLAVESCENT LEAF-HOPPER.

(*Empoasca flavescens* Fav.)

Very similar to the preceding in appearance, size, habits, and distribution is the above-mentioned species (fig. 55). It is sometimes even more abundant. It is paler, nearly white, and has only three spots on the margin of the thorax.

REMEDIES.

As a result of studies of the life economy of leaf-hoppers, it has been ascertained that simply cutting the grass and perhaps some other plants affected, and leaving it in the field, will prevent eggs from hatching; the drying of the stems results in the crushing and distortion of the eggs, owing to the shrinkage of the plant tissues and the curling of the edges of the sheaths.

PLANT-LICE.

Several forms of plant-lice affect the leaves of sugar beet, but as far as at present known do not inflict extensive injury. Among the plant-lice, however, are some few forms which have the habit of feeding on the roots, being known as root-lice, and these are of the greatest importance when atmospheric conditions conduce to their development or the plants are first injured through other causes.

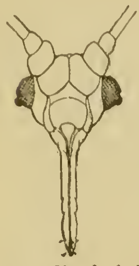

FIG. 56.—Head of plant-louse, showing sucking beak—much enlarged (original, Division of Entomology).

THE MELON PLANT-LOUSE.

(*Aphis gossypii* Glov.)

The melon plant-louse or, as it is more commonly known, the melon louse, is perhaps the commonest species found on beets, and is the best known as well as most destructive of all insects of this class. Fortunately for the beet grower it does not favor this crop, and is usually found only in moderate numbers on beets when other plants are available. The writer has seen a considerable number of this species on beet leaves working in their usual manner by pumping up the juices through their beaks (fig. 56), but although the plants were carefully watched the operations of the plant-lice did not seem to hinder the growth of the plants in any degree. Nevertheless, this louse is capable of serious damage, more especially in the event of exhaustion of favorite host plants, like melons and other cucurbits, which would drive it to beets if these were most available. The principal forms of this insect are illustrated in figure 57.

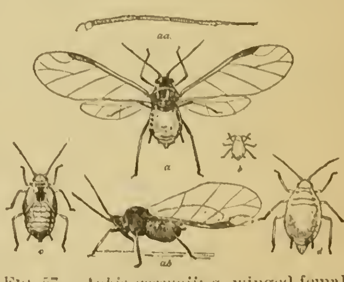

FIG. 57.—*Aphis gossypii*: *a*, winged female; *aa*, enlarged antenna of same; *ab*, dark female, side view; *b*, young nymph or larva; *c*, last stage of nymph; *d*, wingless female—all greatly enlarged (original, Division of Entomology).

The melon louse is probably of American origin and perhaps tropical, since it prefers plants of a tropical nature, has a very wide distribution in North and South America and the West Indies, and has been observed in Australia. It is therefore apt to be present in most fields of sugar beet, but its occurrence there can usually be traced to other plants on which it develops more freely, some of which have already been mentioned. Among others of the favorite host plants are cotton, okra, purslane, strawberry, and orange and other citrus trees. Attack begins in early spring and may last until winter, according to season, climate, and other circumstances.

Natural enemies.—As an illustration of an insect pest held in abeyance and limited to innoxious numbers by natural enemies, no better example could be cited than is afforded by this plant-louse. Its natural enemies include several species of ladybirds or "ladybugs," syrphus flies, aphis lions, the larvæ of lace-wing flies, numerous species of minute hymenopterous parasites, and a parasitic fungus. The insect enemies are most effective in destroying the plant-lice in dry and warm weather. In a cool, damp atmosphere, which is apt to be encountered early in the season when plants are first set out, the insect enemies are as a rule less active, and at such times injury by plant-lice is likely to be most severe.

The species shown in figure 58, known as the convergent ladybird (*Hippodamia convergens*), is one of the most beneficial insects, as it is

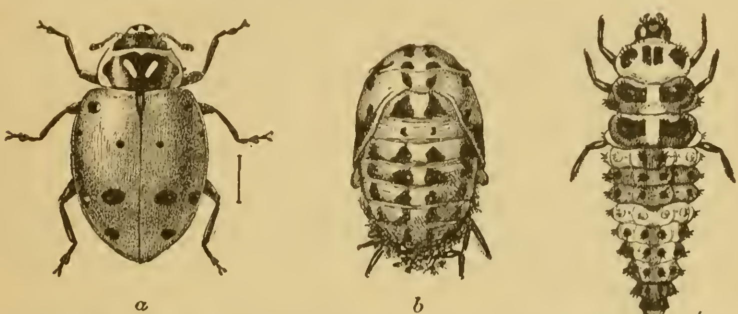

FIG. 58.—*Hippodamia convergens*: *a*, adult; *b*, pupa; *c*, larva—all much enlarged (original, Division of Entomology).

a most active destroyer of plant-lice which feed on vegetables. It is common on sugar beets, and it is interesting to note that on one occasion it was reported as feeding on the leaves of that plant in Oregon (Bul. 26, o. s., Div. Ent., p. 11).

METHODS OF CONTROL.

The melon louse, although a difficult insect to treat when it occurs on cucurbits and some other plants, can be more readily controlled on beets. In fact, all of the leaf-infesting plant-lice can be destroyed on beets by means of sprays and other washes and by some of the ordinary general methods of farm practice.

Kerosene emulsion.—The standard remedy for plant-lice is kerosene-soap emulsion, made by combining 2 gallons of kerosene, half a pound of whale-oil or fish-oil soap or 1 quart of soft soap, with 1 gallon of water.

In preparing this emulsion the soap is first dissolved in boiling water and then poured while boiling hot, but away from the fire, into the kerosene. The mixture is then churned somewhat violently for about five minutes by means of a force pump and direct discharge nozzle throwing a strong stream by pumping the liquid back upon itself. When properly combined the mixture will have become of the consistency of thick cream. It is then placed in moderately tight receptacles, and will keep almost indefinitely until required for spraying, when it is to be diluted. For plant-lice this staple emulsion is usually diluted with from 10 to 15 or 20 parts of water.

Its habit of feeding on the lower surfaces of leaves renders the melon louse more difficult to reach by means of a spray than insects which live on the upper surfaces. In the application of an emulsion or other wash, therefore, it is necessary that the hose be fitted with an upturned nozzle in order to secure the under spraying of the leaves, which is the principal resort of plant-lice and many other sucking insects.

It is of the utmost importance that the sprays or other remedies be applied on the first appearance of the insect in order to check it before it succeeds in obtaining a good start and to prevent its further development.

Spraying with water.—A strong stream of water from a hose directed on plants, so as to hit the insects, is of much value in dislodging them from the plants, to which they do not usually succeed in returning, and where this can be readily done more elaborate remedies are unnecessary.

Pyrethrum administered with a powder bellows to the lower sides of leaves is also valuable and particularly effective on young plants. It is, however, expensive, and can not be profitably used in large fields.

Clean culture and fall plowing should be followed as the most effective measure of prevention of attack by plant-lice as well as other insects, and this includes the keeping down of weeds after the main crop has been gathered until the next crop is planted, this treatment serving to rid the fields of many pests, particularly those which do not fly readily, by depriving them of food.

Fumigation methods.—In very recent years two methods of fumigation have been rather extensively practiced as a means of destroying the melon louse and related insects on valuable plants. It is doubtful, however, if either of these remedies would be necessary on beets except in regions where injury is more extensive than has thus far been reported.

If careful watch is kept for the first appearance of this plant louse it can be more thoroughly eradicated by means of fumigation than by any other method. The method of application of bisulphid of carbon consists in covering the affected plants on the first appearance of the pest with a tub or similar receptacle, and evaporating the chemical beneath this at the rate of a dram to 1 cubic foot or less of space inclosed. A tablespoonful serves for ordinary tubs. This treatment does not injure the plant, and if the tub fits tightly to the ground the vapor of the bisulphid is retained and the lice will all be killed. This remedy is much used by growers of melons and cucumbers who watch their vines carefully, removing and destroying affected plants and fumigating those which can be saved.

THE BEET APHIS.

(*Pemphigus betæ* Doane.)

This insect is a root-louse and comparatively new as a pest. Attention was first drawn to it in 1896, and for three or four years afterwards it did considerable injury to sugar beet in Washington.[a] We do not know its full life history nor its distribution, but it occurs also in Oregon and probably in California. In Oregon a thousand tons or more of beets were ruined in a year in a single valley. This insect is one of many which may be seemingly harmless up to a certain point, but, with a changed environment, become of more importance economically.

The smaller rootlets of beets are first attacked and, when the aphis occurs in large numbers, they are soon destroyed. The loss of these so weakens the plant that it is not able to withstand further attack, and, as a result, the leaves wither and the beet shrivels and becomes spongy. Wild yarrow (*Achillea lanulosa*) appears to be a normal host plant, and when its roots are examined in localities where the insect abounds, they will frequently be found covered with the white woolly excretion of the insect, while the louse itself is feeding on the smaller rootlets. This species also lives on knotweed or door-mat weed (*Polygonum aviculare*), on grasses, and some other plants. It is likely to increase its range, but this may be a matter of slow accomplishment, unless it is introduced from one locality to another on beets in shipment.

METHODS OF CONTROL.

Owing to the large acreage which is planted in sugar beet in many portions of our country, it does not seem probable that we can treat satisfactorily an insect like this root-louse, which feeds underground, by means of insecticides. Kerosene emulsion and bisulphid of carbon will no doubt kill it, but the expense would be excessive were either used on a large scale. Nor can we hope entirely to eradicate the pest when it has taken up quarters in our fields by means of cultural methods. Additional observations on its life history and experiments look-

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[a] Cordes: Sugar Beet Gazette for November, 1899; Doane: Bul. 42, Wash. State Agr. Expt. Sta., 1900, pp. 3–11.

ing to better methods for its destruction are necessary. It has been reported of the beet-root louse, which will receive next treatment, that in spite of heavy flooding and plowing in winter, the exposure of infested soil to frost, the number of the insects the following year was much larger. Nevertheless, in some localities these farming methods might be employed with better success against one or the other of these two insects. The best that can be recommended at the present time is to avoid planting beets on land where other food plants of this root-louse grow and where it is known to be established, and to practice judicious rotation of crops. It is advisable also to search for these food plants and destroy such as are of no value. Where the insects are found here and there in fields it might be found profitable to kill them by means of kerosene emulsion applied to the roots so as to soak down into the ground, making use of this remedy before rainfall or following it where possible with a copious flooding of water.

Possibly in time some of our insect friends, such as certain forms of ladybirds, syrphus flies, or parasitic insects, may come to the rescue and solve the problem. Ants are without doubt associated with this as with other root-lice and serve as distributors of infestation by carrying wingless lice from plant to plant. If ants occur in the same fields and it can be seen that they foster the root-lice, their nests should be sought out and destroyed.

THE BEET ROOT-LOUSE.

(*Tychea brevicornis* Hart.)

The above name is suggested for a subterranean plant-louse described in 1894 (18th Rept. Ins. Ill. for 1891–92, p. 97), and found about corn roots in Illinois. Considerable complaint has been made of injury to sugar beets in Colorado in 1901 and 1902 by what is now considered this species. It was described as sapping great numbers of beet roots, diminishing the stand to a large extent. The winged insect was noticed as early as April 1st. A correspondent of the division of entomology, Mr. W. K. Winterhalter, stated that many fields in the Arkansas Valley were infested, and expressed the opinion that if the pest should continue to spread, the sugar-beet industry might be seriously damaged. It is quite apparent that this insect is increasing as a pest, and that it will be difficult to control, as it has already shown its capability of development on a variety of plants, including wild grasses and cereals, among which are corn and sorghum, and such weeds as pigweed, lambs-quarters, "salt-grass," and purslane.

Remedies.—The remedies to employ are the same as for the preceding species of root-louse.

WHITE GRUBS AND MAY BEETLES.

Several species of white grubs and wireworms, the young of May or June beetles and of "snap bugs" or "skipjacks," respectively, attack the roots of beets, but none of them appear especially to favor this form of food and we have yet to learn of very serious damage by any of them. Both of these forms of insects follow the planting of beets in grass lands, and if some other plant be used as a first crop before the planting of beets in virgin prairie or in sod land the chances of infestation will be reduced to a minimum.

It is recorded that about 15 per cent of a field of beets was once destroyed in Nebraska by white grubs, and the roots of beets in central Illinois have also been injured, causing the plants to wilt. Only two forms of white grubs have been identified with attack on beets, but there are undoubtedly many more which affect this crop.

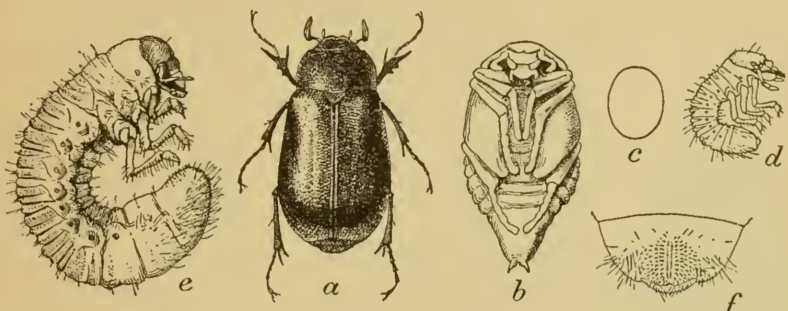

FIG. 59.—*Lachnosterna arcuata: a*, beetle; *b*, pupa; *c*, egg; *d*, newly hatched larva; *e*, mature larva; *f*, anal segment of same from below—*a*, *b*, *e*, enlarged one-fourth; *c*, *d*, *f*, more enlarged (author's illustration, Division of Entomology).

One of the commonest forms of May beetles is illustrated, with its white grub, in figure 59, which also shows the egg and pupa. A more complete account of this species is furnished in Bulletin 19, new series, of the Division of Entomology (pp. 74–80).

THE RUGOSE MAY BEETLE.

(*Lachnosterna rugosa* Mels.)

This species was found by Forbes and Hart in the year 1900 injuring the roots of beets in central Illinois and causing the plants to wilt. The beetle is of about the same size and color as the arcuate May beetle previously mentioned. It is a little paler, however, and the elytra are more distinctly lined with ridges, while the thorax is more strongly and much more closely covered with punctures. Its distribution extends from Massachusetts to Louisiana and Texas, and westward to Colorado and Montana.

METHODS OF CONTROL.

Living as white grubs do, underground, and often at a very considerable depth below the surface, it is obvious that it is a matter of extreme difficulty to reach them with insecticides. Gas lime has been suggested for this purpose, and good results have followed the experimental use of bisulphid of carbon and kerosene emulsion against allied species.

Kerosene emulsion is an effective remedy where small areas, such as beds of strawberries grown for home consumption, are affected. It should be diluted about ten times. and poured over the surface of the ground about the infested plants. It is well to make the application just before rainfall, that it may be washed deep into the soil, so as to come into direct contact with the larvæ. If rain does not fall within a day or two after its application a copious watering should follow.

It is to be regretted that both the bisulphid of carbon and kerosene emulsion remedies are too expensive for use on a large scale, but white grubs may be effectually killed off on lawns and in small fields and gardens by the use of the latter.

Fall plowing.—Everything considered, the most useful remedy is found in fall plowing. The land should be thoroughly broken, so as to leave it loose, and the grubs and their parents, the May and June beetles as well, exposed as much as possible to the elements during the winter. This is particularly valuable in cold weather, as the white grubs are not able to withstand exposure to a severe frost. A cross plowing is sometimes advisable where there is severe infestation. This will insure the ground being often disturbed, and if it is kept clean of weeds and other vegetation the grubs will be held in nearly complete control though not exterminated. Summer fallowing of infested land is said to be useful.

Rotation of crops is also valuable in connection with fall plowing. In case infested meadow land is desired for the planting of beets, corn, strawberries, or other crop subject to severe injuries by white grubs, an application of fertilizer, such as nitrate of soda or kainit, put on as a heavy top dressing after the ground is prepared and before planting, has proved of benefit in some cases.

Domestic animals.—Chickens and turkeys, as well as several species of insectivorous birds, are efficient destroyers of white grubs, and much good may be accomplished by encouraging domestic fowls to follow in the furrows to pick up the grubs as they are turned up by the plow. Hogs, as is well known, are also exceedingly fond of white grubs, and if allowed the run of localities where these are abundant, after the crop is made, they will root up the ground and devour great numbers of them. These and many wild animals also kill and devour the beetles when they have opportunity.

Care in the selection of manure.—As manures are frequently infested by white grubs, some of which are at times troublesome, it is well to exclude such forms as experience has shown to contain an excess of these creatures, as, for example, horse manure. The white grubs can be identified readily by disintegrating the material, and chickens and other fowls can be utilized in destroying them before the manure is spread on the fields.

Attracting to lights.—May beetles are strongly attracted to lights, and especially to electric-light globes. They can be captured to some extent by means of stationary lanterns and pans of water, on which is floating a thin scum of kerosene, placed below the lanterns. The traps should be stationed at intervals about an infested field, particularly around its borders.[a]

THE CARROT BEETLE.

(*Ligyrus gibbosus* DeG.)

This beetle was reported during the year 1890 by Professor Bruner as having been quite destructive to the sugar beet in the western portion of Nebraska. They worked for the most part on old ground where irrigation was practiced, and their operations extended on the roots from the surface of the ground to 3 or 4 inches below; in some instances 7 inches.[b] This insect is better known as a carrot pest, and is, in fact, one of the worst known enemies of carrot, parsnip, and some related plants. Injury is due to both larvæ and beetles. Young corn is often cut just above the roots, and the root crops mentioned are punctured with little holes, rendering them unfit for market. Tubers of potato and sweet potato are also subject to attack, as are the roots of celery. Other plants affected include the roots and tubers of sunflower and dahlias as well as cotton.

FIG. 60.—*Ligyrus gibbosus*: adult—enlarged (original, Division of Entomology).

The beetle closely resembles the May beetle, but it will be noticed by reference to figure 60 that the surface of the wing-covers is strongly sculptured and coarsely punctate. The beetle measures about a half to five-eighths of an inch in length, with considerably shorter legs than in the true May beetles. The dorsal surface is similarly colored,

[a] NOTE.—It is often desirable to protect choice trees against the ravages of the beetles. For this purpose nothing is better than mosquito netting. Beetles may be beaten from the trees into inverted umbrellas or similar receptacles, and can be readily captured and killed, as they make little effort to escape after being dislodged. Spraying with arsenicals is of no practical use, as the beetles continue feeding until the poison takes effect, and the next day the dead are replaced by other individuals.

[b] For particulars see Bul. 23, o. s., Div. Ent., p. 17.

but the lower surface is reddish brown and the legs are clothed with reddish-yellow hairs.[a]

Remedies.—Unfortunately the carrot beetle works under ground, like common white grubs, and for that reason is as difficult to control. Injury is largely confined to the beetles, although the larvæ do some injury. If we could ascertain the principal breeding places, this might furnish a solution of the problem. The grubs may be treated as described in preceding paragraphs. In a case of reported injury to the roots of sweet corn in Minnesota in 1902 the presence of the carrot beetles was traced to their having developed in horse manure on the infested grounds;[b] hence avoiding the use of this as a fertilizer or the destruction of the white grubs in the manure is recommended. Crop rotation is one of the best remedies, and it is probable that trap lights might yield good results, as these insects are more attracted to bright lights than are ordinary May beetles, although it is not known to what extent the beetles might be lured from the fields after they have begun to feed.

WIREWORMS.

The sugar beet, as has been said, is so nearly exempt from injury by wireworms that this plant, as also spinach, might be profitably used as an alternate in the cultivation of corn, various other cereals, and vegetable crops, such as potatoes, which are frequently very badly infested by these insects. Occasionally wireworms of several species have been found eating into the smaller roots of beets and burrowing into the tap roots and crowns, causing the plants attacked to shrivel and die. Messrs. Forbes and Hart have indicated two species of wireworms as having been concerned in such injury, *Melanotus cribulosus* and *Drasterius elegans*, both of which have been observed about beet roots which had been more or less injured and eaten away.

The term wireworm is applied to numerous forms of elongate wire-like creatures, the larvæ of snapping beetles or "snap-bugs," of the family Elateridæ. Many species are injurious to cultivated crops and are often very troublesome in cornfields. A large proportion of the wireworms are shining yellow in color, while many of the adults, like the species figured, are brown and covered with close brown or yellowish pubescence.

The life history of injurious subterranean species is in some respects similar to that of white grubs, the beetles being among the earliest spring arrivals, occurring in April and May, and flying rapidly in the heat of the day.

The eggs are generally deposited in moist places grown up with grassy vegetation, weeds, or corn, and the larvæ upon hatching feed,

[a] A more complete account is given on pp. 32–37 of Bul. 33, n. s., Div. Ent.

[b] Washburn, 7th Rept. Ent. Minn. for 1902, pp. 47–49.

like the white grubs, upon the roots, developing slowly and requiring about the same period for the perfection of the life cycle—about two or three years. Like the white grubs, also, the wireworms transform to pupæ in autumn, and the change to the beetle form takes place before winter, the beetles usually remaining in a quiescent state until their emergence the following spring.

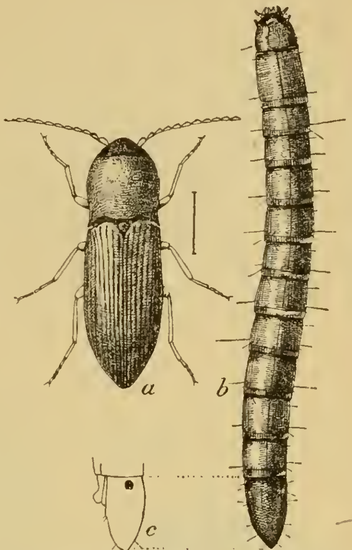

Fig. 61.—*Agriotes mancus: a*, beetle; *b*, larva; *c*, anal segment of larva in profile—about four times natural size (author's illustration, Division of Entomology).

Two common and injurious species are chosen as examples of this class, although it must be remembered that they have not been determined as beet feeders. The first is known as the wheat wireworm (*Agriotes mancus* Say), and is shown four times natural size in figure 61. The other is called *Monocrepidius vespertinus* and is introduced here because known in its three principal stages (fig 62).

Remedies.—Owing to their extremely hardy character, indicated by the hard, firm texture which has given them the name of wireworms, as well as to their subterranean nature, these insects are even more difficult to treat satisfactorily than the white grubs. Of direct applications, poisons are of little value, but salt in large quantity has been used by some persons with success for many years, and has been reported to be one of the most effective applications that can be made. Strong brine, however, must be used with caution, as it sometimes destroys certain forms of plant life. Different forms of salty fertilizers are also said to be of value, both as stimulants to the affected plants and as insecticides. Among these are kainit and nitrate of soda.

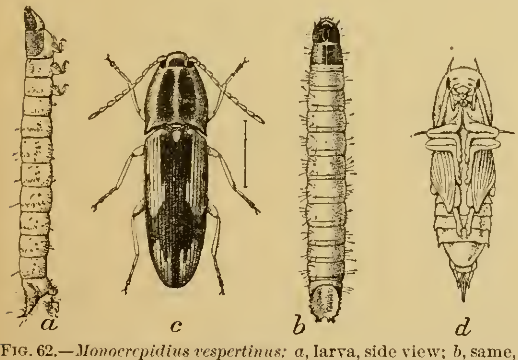

Fig. 62.—*Monocrepidius vespertinus: a*, larva, side view; *b*, same, dorsal view; *c*, beetle; *d*, pupa—about three and one-half times natural size (author's illustration, Division of Entomology).

Clean cultivation and poisoned baits are also recommended, the same as for white grubs. In fact, where remedial measures are in use against either cutworms or white grubs, they apply also to wireworms, but are less effective.

One of the best forms of bait to be used consists of slices of potatoes or other vegetables poisoned in the same manner as advised in the consideration of cutworms.

MISCELLANEOUS ROOT-INFESTING INSECTS.

In addition to white grubs, wireworms, and root-lice, which have been treated as invading the underground portion of beets, a few other species are found at the roots. Prominent among such are the seed-corn maggot and the clover-root mealy-bug. A number of complaints have been made of injury by insects which lead to the belief that the seed-corn maggot is frequently found on beets, although instances which could be positively traced to this species are comparatively few.

THE CLOVER-ROOT MEALY-BUG.

(*Dactylopius trifolii* Forbes.)[a]

This species, as its common name indicates, is better known as an enemy of clover, on the roots of which it feeds. In 1901, however, it appeared in considerable numbers on sugar beet in Michigan, the smaller stunted roots being invariably infested. Injury was most apparent in June. The female mealy-bug measures a little more than one-twelfth of an inch in length, is reddish brown, and covered with a waxy or mealy secretion. The legs are dirty yellow, and from the sides project in the manner usual to this group 15 to 17 waxy filaments, the shortest being near the head and the longest near the tail, sometimes one-third as long as the body. It is related to the scale insects and is of similar appearance to the species shown in figure 63.

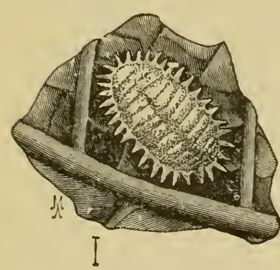

FIG. 63.—*Dactylopius citri*: female—enlarged (Division of Entomology).

Remedies.—The same methods of control that have been prescribed for root-lice would operate against the present species, with about the same results.

THE SEED-CORN MAGGOT.

(*Pegomya fusciceps* Zett.)[b]

Beet roots are subject to attack by the above-named species of root maggot. During November of 1902 we received complaint of what was with little doubt this insect from Colorado, where it was breeding in rot-infected roots, apprehension being expressed that

[a] Syn: *Coccus trifolii* Forbes; 14th Report State Ent. Ill. for 1884 (1885), pp. 72–73; Pettit: Bul. 200, Mich. Agr. Exp. Sta. for 1901 (1902), pp. 193–194; Davis: Insect Life, Vol. VII, p. 172.

[b] See Bul. 33, n. s., Div. Ent., pp. 84–92, for synonymy, bibliography, etc.

although injury was not then noticeable the insects might do damage the following spring. Such a sequel is often to be expected, and it seems probable that many reported instances of injury by this and related forms of maggots are due to their habit of developing on decaying vegetable and other matter and afterwards attacking roots and taproots and other healthy vegetation of the vicinity. Most vegetables, more particularly beans, peas, and maize, are subject to damage, and cabbage, turnip, radish, onions, and sweet potatoes are also much affected. The insect which is generally distributed in the United States is shown in its different stages in figure 65. It resembles the beet or spinach leaf-miner previously considered. The particularly distinguishing characteristic of the fly consists of a row of short bristly hairs of nearly equal length on the inside of the posterior tibiæ of the male (fig. 64, *a*). The length of the wing is about one-fifth and of

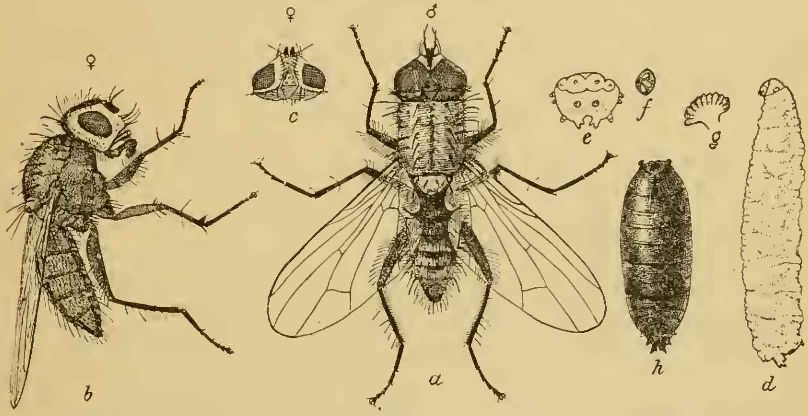

FIG. 64.—*Pegomya fusciceps*: *a*, male fly, dorsal view; *b*, female, lateral view; *c*, head of female, from above; *d*, larva, from side; *e*, anal segment of larva; *f*, anal spiracles; *g*, thoracic spiracles; *h*, puparium—all much enlarged (author's illustration, Division of Entomology).

the body about one-sixth of an inch. The maggot as well as fly resembles the onion maggot. There is little doubt that this insect is of European origin, and it is certainly increasing in destructiveness in this country.

Remedies.—Owing to the difficulty of destroying subterranean pests and the cost of chemicals for the purpose, such as bisulphid of carbon, we have to depend more upon methods of prevention. One way of deterring the parent flies from depositing their eggs consists in the use of sand soaked in kerosene—a cupful to a bucket of dry sand—which is placed at the base of the plants, along the rows. This also kills young maggots that may attempt to work through the mixture.

Fertilizers are also useful as deterrents, particularly when employed just before or after a shower has thoroughly wet the ground. They should be applied as nearly as possible to the roots, and the earth should be turned away from the plants for this purpose. They possess the advantage of also acting as a stimulant to plant growth. Stable manure is apt to induce infestation, as this species is well known to develop in excrement and other decomposing material. As soon as plants show signs of wilting and maggots are known to be present, the injured plants should be promptly pulled and destroyed.

The above methods have been used with success against onion maggots and similar root-feeding species, and may be all that is required in the case of ordinary infestation of beets.

One of the best remedies for root maggots is bisulphid of carbon. It has been used with more or less success by Prof. A. J. Cook and others since 1880. In its application great care should be exercised that the liquid shall not come in direct contact with the roots of the affected plants. Directions for the treatment of plants affected by root maggots are furnished on page 14 of Farmers' Bulletin 145, a copy of which can be had upon application to the Secretary of Agriculture.

THE RED SPIDER.

The common or two-spotted red spider (*Tetranychus bimaculatus* Harv.) is usually present in most fields of sugar beet east of the Rocky Mountain range, but it is preeminently a greenhouse pest, and as a rule does comparatively little injury to plants growing out of doors. It is unique as a vegetable pest in that it is not a true insect, nor even a spider, as the popular term would imply, but a spinning mite. As the word mite indicates, these creatures are extremely minute, and are frequently not noticed until they become excessively numerous, as is apt to happen during summer droughts. They do considerable damage in flower and vegetable gardens, but attain their greatest destructiveness in connection with plants grown under glass.

The general appearance of the common red spider is shown in figure 65, highly magnified. The length of a full-grown individual is only about one-fiftieth of an inch. The ground color is reddish, usually more or less tinged with yellowish or orange, and most individuals have a dark spot on each side, due to the food contents of the body. The young are similar to the adults, differing in having only three pairs of legs, while the adults have four. This red spider spins threads, but does not use them for climbing. The threads are frequently so numerous as to form a tissue visible at a little distance. Webs are usually constructed on the under sides of leaves and within them the mites feed and lay their eggs from which the young develop.

This red spider is quite likely of foreign origin, but its distribution has not been carefully studied.

It is inclined to be omnivorous, attacking a wide range of plants. As the red spiders increase in number the leaves of an affected plant turn pale and become stunted, and eventually the whole plant succumbs unless remedies are applied. Cuttings and young rooted plants are especially susceptible to injury, and more particularly in spring. These mites injure by suction, slowly reducing the vitality of plants until in time their functions are more or less deranged. Among ornamental plants that are much affected are violet, rose, clematis, minnet, pink, fuchsia, pelargonium, godetia, passiflora, feverfew, thunbergia, verbena, heliotrope, moonflower, calla, smilax, and Easter lily; while of other crops, beets, beans, sage, tomato, eggplant, pepper, cucumber, squash, cowpea, hops, and berries of various kinds are attacked. As a rule this species is not especially harmful to the sugar beet but is quite destructive at times in fields of other crops; for example, to beans, which have been badly injured in South Carolina in recent years.

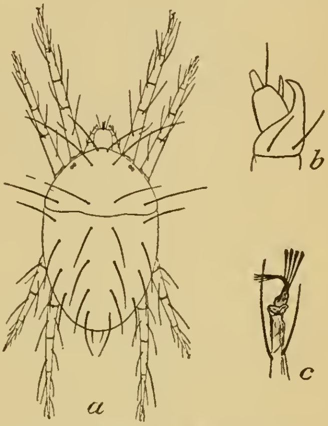

FIG. 65.—*Tetranychus bimaculatus*: *a*, adult; *b*, palpus; *c*, claws (after Banks, Division of Entomology).

Remedies.—This red spider is resistant to "gassing" or fumigation, either with tobacco or hydrocyanic-acid gas. It is, however, peculiarly susceptible to sulphur, a sovereign remedy for mites in general. Flowers of sulphur mixed with water at the rate of 1 ounce to the gallon and sprayed over the plants is of great value in its eradication; or the sulphur may be combined with a wash, for example, with strong soapsuds.

Potash, fish oil, whale oil, and other soap solutions, resin wash, and kerosene-soap emulsion are also valuable, and the addition of sulphur increases their effectiveness; but these washes are too strong for some delicate plants and are apt to injure them. For violets and similar plants, as they occur in greenhouses, no other remedy is used by florists generally than frequent syringing or spraying with water or with a solution of neutral soap. Directions for the application of the soap washes to violet and other greenhouse plants are furnished in Bulletin 27, new series, of the Division of Entomology (pp. 40–42).

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U. S. DEPARTMENT OF AGRICULTURE,

DIVISION OF ENTOMOLOGY—BULLETIN NO. 44.

L. O. HOWARD, Entomologist.

SOME

DIV. INSECTS.

MISCELLANEOUS RESULTS

OF THE

WORK OF THE DIVISION OF ENTOMOLOGY.

VII.

PREPARED UNDER THE DIRECTION OF THE ENTOMOLOGIST.

234955

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1904.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Entomology,
Washington, D. C., February 24, 1904.

Sir: I have the honor to transmit herewith the manuscript of a bulletin which contains several articles and notes similar in nature to those which have been presented in previous years under the title, "Some miscellaneous results of the work of the Division of Entomology," and recommend that the material here presented be published as Part VII of that series. The introductory article on aphides affecting grains and grasses is of special value to the economic entomologist, as the identity of many of these species has been in a state of confusion for a number of years, and the descriptions here furnished, together with the illustrations, will assist materially in simplifying this matter. For many years there has been great demand for a publication covering the subject of the weevils which affect chestnut, as also pecan and hickory, and the article presented on this subject will, in part, fill this want. The remaining articles are mostly shorter, and each has its special value.

Respectfully,

L. O. Howard,
Entomologist.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

[a]Presented by title before the St. Louis Meeting of the Association of Economic Entomologists, Dec. 30 and 31, 1903.

ILLUSTRATIONS.

SOME MISCELLANEOUS RESULTS OF THE WORK OF THE DIVISION OF ENTOMOLOGY.

VII.

ON SOME OF THE APHIDES AFFECTING GRAINS AND GRASSES OF THE UNITED STATES.

By Theo. Pergande.

THE EUROPEAN GRAIN LOUSE.

(*Siphocoryne avenæ* Fab.—Fig. 1.)

Up to the present time the writer has been unable to ascertain whether other species described in Europe or this country are identical with this insect or not, though it is quite certain that the accounts or descriptions published by the earlier entomologists of this country on the apple louse all refer to the same species, particularly since the genuine *Aphis mali* DeGeer was first observed by the writer in the spring of 1897, from which date it has spread through several of the Eastern States.

The first elaborate account of the common apple louse of the United States was published by Dr. Asa Fitch in his First and Second Report for 1856, under the cognomen of "The apple plant-louse," which he erroneously considered to be identical with the European *Aphis mali*, to which since his time it has been referred by subsequent authors. These authors took it for granted that Doctor Fitch knew the species well, though all of them were unaware of the range of food plants to which the species adapted itself during its cycle of existence. It is really strange that Fitch, after having seen thousands of the apple louse, should have considered the insect found by him on the leaves of the plum to be a different species, which he subsequently described on page 123 of the same report, under the name of *Aphis prunifoliæ*, notwithstanding that, as stated by himself, "Its generation and habits are so similar to those of the apple plant louse that a separate account would be little more than a repetition of what has already been related."

.To make the history of the species still more complicated, leading later on to many errors, Fitch published (on pp. 91, etc., of his Sixth

Report for 1856) a very interesting article on the grain *Aphis* (*Aphis avenæ* Fab.), in which he made the unfortunate mistake of confounding several other species with the true grain louse; erroneous figures of one of which were published on Pl. I, figs. 5 and 6, representing a species of Siphonophora *Koch*. This error of judgment in distinguishing genera as found upon grain has mainly been the cause to divert the attention of later entomologists from the true characters of the species described by Fabricius.

Until the spring of 1880 the writer also entertained the opinion that the species treated of by Prof. Cyrus Thomas, in his Eighth Report (pp. 51–55), was identical with that mentioned and described by Fitch as *Aphis avenæ* Fab. During the spring of 1880, however, the writer became suspicious that something was wrong, since the description given by Thomas did not agree with that published by Fabricius. At that time I happened to examine a lot of aphides from Pocomoke City, Md., which were reported to be extremely numerous and destructive to wheat in that vicinity. These, in my opinion, agreed exactly with the description of *Aphis avenæ* Fab., and Kaltenbach, but not with the description by Thomas, and I have held to this opinion ever since. The same form, having been found by myself or received from various localities, infesting grains or grasses, agrees well with the description of the species published by Fitch, but not with that of Thomas.

In consulting Mr. O. W. Oestlund's description of his *Nectarophora granaria* (Aphididæ of Minnesota, p. 82, 1887), I am forced to believe that the species observed by him is also the same as the *A. avenæ* Fab., though, having failed to obtain any specimens from him, I am unable, at present, to verify my suspicion.

While consulting the original notes of Doctor Fitch, I found also a clipping from the Kingston (Canada) Daily News, of August 16, 1866, containing an article on the grain louse which was doing much damage at the time. The article was written by a Mr. Lawson, of the Botanical Society of Canada, who considered the insect as new, and in the same article he described it under the name of *Aphis tritici*. After a careful scrutiny, I am confident this is the same as *A. avenæ* Fab., but, since descriptions of insects in newspapers are not considered as authoritative, I have declined to recognize his name of the species.

During the fall of 1880, while solving the life history of the hop louse (*Phorodon humuli*) at Richfield Springs, N. Y., at a time when the return migrants of the apple louse were very abundant on the leaves of apple trees or still swarming, I happened to discover also some colonies, both of the migrants and the apterous forms, in various stages of development on the leaves of a grass, *Dactylis glomerata*, growing in the orchard. After careful comparison of these with others on the apple, which, up to a comparatively recent time the writer had considered identical with the European apple louse, *A. mali* DeG.

Some years ago I examined and compared a number of specimens, labeled by Fitch, and now contained in the collection of the United States Department of Agriculture, both of his *A. mali* and his *A. avenæ*, as well as a number of specimens of *A. avenæ* kindly sent me by Dr. H. Schouteden, Brussels, Belgium, all of which confirmed my opinion which is that the American apple louse and the grain louse are identical, and that the European *A. mali*, of which the first American colonies were found in the spring of 1897, is quite a distinct species, not even generically identical with the genuine grain louse of Europe, nor with the grain louse described by Thomas as *Siphonophora avenæ*. On further examination and comparison of the insect under consideration, I have concluded that it belongs to the genus Siphocoryne of Passerini, described in "Aphididæ Italicæ" (p. 52, 1863). He there states that the nectaries are clavate, while otherwise it is similar to Aphis, placing with it but three species; failing, however, to discover the clavate character of the nectaries in *avenæ*, which occasionally exhibits this character but faintly, so as to make them appear cylindrical and was therefore still retained by him in the genus Aphis; whereas in the true genus Aphis the nectaries are always more or less distinctly tapering.

According to my own observations, after the migrants had been transferred from apple and Cratægus to grain and grasses. I have found a certain range of variation in the comparative length in the joints of the antennæ, as well as in the nectaries of the progeny of the apple louse, the extreme forms of which may easily induce superficial students to consider them as distinct. Large series, however, of the various forms, more or less due to the season or abundance of food, have convinced me that all of them belong to but one species. Some of the most constant characters of this insect are the comparatively small or minute terminal fork of the front wings, which frequently varies considerably in the same specimen; the more or less strongly pronounced tuberculation of joints three and four and frequently also the fifth joint of the antennæ, and the clavate character of the nectaries, which frequently becomes rather pronounced.

Observations thus far made tend to show that the species is biennial and that the progeny of the spring migrants from the apple subsist almost exclusively upon various grains and grasses until the fall of the second year, when a generation of return migrants makes its appearance. The earliest ones of these produce the sexual females, whereas the others, appearing several weeks later, are the true males, thus closing the cycle of existence of the species. These observations show also that the progeny of the migrants from the apple are rarely seen during the heated term, and that most of them station themselves close to the base of the plants; though I have, on one occasion, also found a colony of *Siphocoryne avenæ*, including the winged form, about the middle of August, on the leaves of *Panicum sanguinale*, in which the characters above mentioned were still those of the genuine apple plant louse. This similarity was evidently due to the general dryness of grasses common during summer, whereas from September till winter and the following spring, grasses as well as grain became more succulent and nourishing, with the result that nectaries as well as antennæ developed more rapidly as the season and growth of plants advanced. These organs reached their maximum development toward the end of June, after which a general retardation set in, until the sexupares or return migrants were almost identical with those found on the apple during the spring, though stray specimens may frequently be encountered during the season, which indicate an overlapping of two different series.

The annexed list is for the purpose of indicating the localities and plants on which the grain louse has thus far been observed:

Apple (*Pyrus malus*), United States, April to June, and September to November.

Pear (*Pyrus communis*), Washington, D. C., October and November.

Hawthorn (*Cratægus coccinea*, etc.), Washington, D. C., May and November; Newark, Del., November.

Quince (*Cydonia vulgaris*), Washington, D. C., May and November; St. Louis, Mo., June.

Plum (*Prunus* sp. ?), Washington, D. C., June; Richfield Springs, N. Y., May.

Choke cherry (*Padus virginiana*), Oakwood, Nebr., October.

Wild black cherry (*Padus serotina*), St. Louis, Mo., October.

Dogwood (*Cornus* sp. ?), St. Louis, Mo., October; evidently accidental.

Celery (*Apeum graveoleus*), Washington, D. C., November; with larvæ.

Tickseed (*Coreopsis* sp. ?) Brookings, S. Dak., September; with larvæ.

Shepherd's-purse (*Capsella bursa-pastoris*), Washington, D. C., November; probably accidental.

Burdock (*Lappa major*), Washington, D. C., November; accidental.

Wheat (*Triticum vulgare*), Washington, D. C., March to June; Pocomoke City, Md., April; Adonia, Va., April; Trenton, N. J., May; Massachusetts, November; Carroll, Ohio, October, November; Wooster, Ohio, January; Lafayette, Ind., June; Laporte, Ind., December; Sherman, Tex., April; Los Angeles, Cal., April; Champaign, Ill., November.

Rye (*Secale cereale*), Atlanta, Ga., April.

Oat (*Avena sativa*), Washington, D. C., November; St. Louis, Mo., November.

Meadow grass (*Poa pratense*), Washington, D. C., October to December

Bluegrass (*Poa compressa*), Ashland, Nebr., October.

Timothy (*Phleum pratense*), Washington, D. C., August, November.

Finger grass (*Panicum singuinale*), Washington, D. C., August, November.

Orchard grass (*Dactylis glomerata*), Richfield Springs, N. Y., October.

Upright chess (*Bromus racemosus*), Washington, D. C., June.

Rescue grass (*Bromus unioloides*), Washington, D. C., January, 1903.

Thus far 22 plants are herewith recorded on which the species has been observed, of which 8 are trees, 4 are weeds or herbs, and 9 grains or grasses.

Siphocoryne avenæ Fab.

Aphis avenæ Fab., Entomologia Systematica, Vol. IV, p. 214, 1794.

Aphis mali Fitch, First and Second Reports on the Noxious and Beneficial Insects of New York, p. 49, 1856.

Aphis prunifoliæ Fitch, First and Second Reports on the Noxious and Beneficial Insects of New York, p. 122, 1856.

Aphis avenæ Fitch, Sixth Report of the Noxious and Beneficial Insects of New York, p. 91, 1856.

Siphonophora avenæ Thomas (in part), Eighth Report, Noxious and Beneficial Insects of Illinois, p. 52, 1879.

Aphis annuæ Oestl., Synopsis of the Aphididæ of Minnesota, p. 66, 1887.

Aphis fitchii Sanderson, Thirteenth Annual Report Delaware College, Agricultural Experiment Station, p. 137, 1901.

DESCRIPTION OF THE SPECIES.

Winter egg.—The hibernating or winter eggs are deposited during the months of October to December on the trunk and branches of the apple, pear, quince, hawthorn, and plum, under loose bark, in cracks, depressions, in the crotches, and around the buds, where they remain dormant until the following spring. They are about 0.6^{mm} in length, pitch black, and highly polished. In favorable years they become frequently so numerous as to cover entire branches, when they may be readily observed. Yet, notwithstanding the great number of eggs, the majority, through one cause or another, are destined to perish during the coming winter, when numbers of them are washed off by rains, sleet, or snow.

Stem-mother; first generation.—The young larvæ, hatching from these eggs, make their first appearance, according to the advancement of the season, from about the middle of March to the middle of April, at about the time that the buds commence to burst. They are at that time about 0.6^{mm} in length, at first yellowish green, though changing within a few hours to a rather dark green; the head changes to dusky or almost black in front and the eyes to a dark brown. The legs are dusky, rather stout, and somewhat hairy. The antennæ are short and four jointed, with the third and the spur of the fourth much the longest and subequal in length. The nectaries are very short and tuberculiform, while the rostrum reaches almost to the end of the body. Within about a month after hatching they reach maturity. The mature stem-mother measures about 1.4^{mm} in length, by almost one-half of it in diameter about the middle of the abdomen. They are now of a greenish-yellow color, with the medio-dorsal line dark green, while the head, the first three joints of the antennæ, the greater part of the legs, the lateral border and incisures of the abdomen are rather pale. The remainder of the antennæ, sometimes also the entire legs and tail, are dusky and the eyes brown, while the nectaries are still paler than the body, with the apex only dusky. All are covered with an extremely delicate, pruinous secretion, which is often almost invisible above, though generally more conspicuous on the under side of the body. The antennæ are rather slender, about one-half the length of the body and five jointed; the third joint is much the longest and almost as long as the rest beyond it. The nectaries are quite slender, cylindrical or somewhat stouter at base, though frequently with a slight indication of becoming clavate toward the end, and with the apex more or less distinctly flaring; they reach generally to or beyond the end of the body and are about as long as the spur of the last antennal joint. The tail is elongate conical, about half the length of the nectaries, covered with minute points and provided with a few bristles each side. The last abdominal segment is semicircular, its edge lined with minute, acute teeth, and fringed with a series of bristles.

Second generation.—The majority of the progeny of these stem-mothers reach maturity during the first half of May, almost all of which acquire wings, to enable them to spread from tree to tree or from one locality to another, for the preservation of the species, as otherwise they are liable to extermination by various enemies, which gradually increase in numbers and species.

The pupæ measure about 1.8^{mm} in length, and are of a more or less translucent,

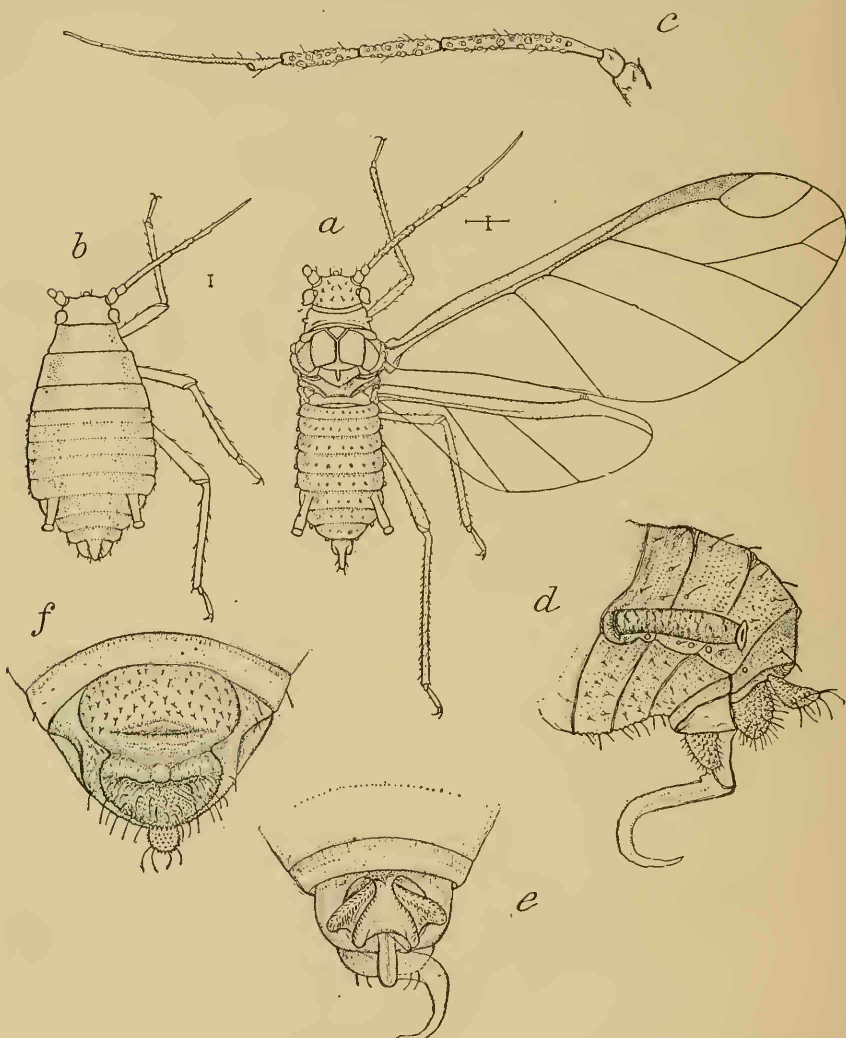

FIG. 1.—*Siphocoryne avenæ* Fab.: *a*, migratory female; *b*, sexual female; *c*, antenna of migratory female; *d*, side view of end of body of winged male; *e*, under side of end of body of male; *f*, under side of end of body of sexual female; all greatly enlarged (original).

pale, greenish-yellow color, marked with three darker green stripes, which are linear on the thorax and much the broadest on the abdomen. The head, four basal joints of the antennæ, the wing-pads, and nectaries are whitish, often with a greenish or yellowish tinge; frequently there is also a reddish or ferruginous patch near the inner base of the nectaries; the future ocelli are indicated by brownish spots. The remaining joints of the antennæ, the tarsi and tip of nectaries are blackish, the apex of the femora brownish or purplish, and the tibiæ dusky toward the end. The antennæ are six jointed, the third joint and the spur longest and subequal in length, each of them almost subequal to joints four and five combined. The nectaries are similar to those of the stem-mother, with traces of the future clavate character of the imago.

Migratory female (fig. 1, *a* and *c*); *second generation.*—The winged form of this generation is extremely active and may be observed at favorable times to swarm in considerable numbers, and, settling on the proper kind of trees, proceed at once to deposit their young ones. The head and thorax of these migrants are of a polished black, with the depressions or sutures of the thorax more or less distinctly greenish; the eyes are brown; the antennæ, terminal two-thirds of the femora, apex of the tibiæ, the tarsi, and nectaries are black. The abdomen is greenish yellow, marked with three or four black, lateral spots in front and one or two beyond the nectaries; the tail varies from dusky to black. The basal section of the femora and the tibiæ vary between green and yellowish green, whereas the median line and lateral margin of the abdomen are frequently dark green. The expanse of their wings is about 7^{mm} and the length of the body 1.5 to 2^{mm}. The antennæ are rather short and stout and reach to or somewhat beyond the middle of the body; in the length of the various joints there is more or less variation in different specimens and frequently in the same specimen; the third joint and the spur are longest and generally subequal in length, with the fourth next and the fifth shorter than either of them. Joint 3 is always strongly tuberculated, frequently also the fourth and sometimes also, more or less so, the fifth. The nectaries are of medium size or generally about as long as the fourth antennal joint; as a rule more or less, though sometimes distinctly clavate, with the bulge toward the end and most conspicuous on the inner side; the apex is flaring. The tail is curved upward, rather less than half the length of the nectaries, elongate conical and rounded at the apex; its surface bears numerous minute points, while on each side of its terminal half are about three curved bristles; the last abdominal segment is similar to that of the stem-mother. The venation resembles that of Aphis; the stigma is elongate lanceolate and its vein arcuate, while the terminal fork of the third discoidal vein is smaller than usual, sometimes minute or even wanting in one wing or the other.

The third generation is composed of both the apterous and the winged forms which reaches maturity about the middle of May, while the fourth generation, which has spread to various related trees or shrubs, makes its appearance about the middle of June; the last or fifth generation, which is usually small and scattered, may be observed from the middle of June till the early part of July, after which time all have disappeared, leaving the trees free of them until the middle of September, when the pupiferous females or return migrants again make their appearance and continue to do so until the middle of November, to restock the trees with sexual females, which it takes about a month to bring to maturity, by which time, or from about the middle of October, the winged males make their appearance, having in the intervening time attained maturity on grain or grasses, and continue to do so till the middle of November or, during favorable seasons, even later.

The pupiferous females, or return migrants, are as a rule somewhat larger than the spring migrants; their expanse of wings ranges between 6 to 8^{mm} and the length of their body between 1.5 to 2.4^{mm}; the antennæ are also somewhat longer, with the third joint usually much shorter than the spur, though joints three to five vary just as much in length and tuberculation, as well as in the size of the terminal fork, from the spring migrants. The general coloration of the body has also become quite variable. In some specimens the color is of a rather yellowish green with the lateral spots very distinct, whereas in others it is of a grayish-green or dusky shade, or sometimes almost black. All except the palest forms show a more or less distinct bronzed reflection on the dorsum, the under side being generally paler and covered with a more or less distinct pruinous secretion. Otherwise they are like the spring migrants.

Sexual female.—The mature sexual females (fig. 1, *b* and *f*) measure from 1.6 to 1.8^{mm} in length; they are oval and almost equally tapering toward each end. The antennæ are short, about half the length of the body, and five-jointed, the spur being the longest, with the third joint somewhat shorter; all of the joints are plain. The nectaries are short, and do not reach to the end of the body; they are usually tapering, cylindrical, or rarely slightly clavate; the tail is still shorter, its basal half rather broad, with the sides parallel, while the terminal part is broadly triangular and covered with minute sharp points. The posterior tibiæ are more or less distinctly inflated and provided with numerous circular, sensorial pores. The color of these sexual females varies more or less; some are of a pale, dirty orange, marked with irregular dusky spots, while others are still darker, spotted only along the sides; many are entirely of a greenish dusky color, often exhibiting in front of the nectaries a lateral row of small, oval, whitish spots; all are, however, provided with a reddish shading around the base of the nectaries. The eyes are brown, the antennæ, legs, and tail dusky and the nectaries black. Each of them contains from two to four or five eggs. These females, either before or after copulation, forsake their position on the leaves or branches and commence to travel restlessly about, in order to select a secure spot for depositing their eggs, when, especially during warm days of October, every part of a tree may be seen covered with them, either in copula or engaged in depositing their eggs.

Male.—The males (fig. 1, *d* and *e*) as a rule are generally smaller than the migratory females; their expanse of wings ranges between 5.4 to 7^{mm} and the length of their body between 1.2 to 2^{mm}. The general appearance of the male is very similar to that of the migratory female, though the abdomen is narrower and the last two segments more protruding. The general color of the abdomen is either orange or greenish yellow, though frequently there is a more or less defined, dusky, median line, terminating, between the nectaries, in a dusky spot. The antennæ are generally somewhat longer and stouter than in the migratory female; joints three and four more strongly and more densely tuberculated and the spur longer than joint three. The genital armature consists of two elongated, triangular lobes or claspers, rounded at the end and covered with erect hairs, between which projects a cylindrical sheath, containing the colorless and flexible organ, which frequently may be observed extruding in a hook-like fashion.

Before maturity of the females the males rest motionless on the under side of the leaves from which they draw their nourishment, though no sooner have the females cast their last skin than they become very nervous and restless and walk briskly about on the branches and the trunk on which the females have congregated, so that frequently thousands of both sexes may be observed, among them many in copula, and often several males may be seen paying attention to the same female.

All of those destined to produce a sexual generation the following fall remain and multiply on grains and grasses, though producing at certain times a migratory form to enable them to spread and to protect themselves against destruction over a large area of the country, during which time for a greater or less extent certain external changes take place, the extreme forms of which may easily pass as distinct species, when toward the second fall they return again to the original form.

NATURAL ENEMIES AND PARASITES.

Fitch, in his admirable work on the apple louse, refers to the larvæ of various aphis lions (Chrysopa) and ladybirds (Coccinellidæ) as being very effective in keeping the aphides in check, whereas in connection with the grain aphis he mentions the following parasitic or predaceous insects.

Toxares triticaphis Fitch; *Praon avenaphis* Fitch; *Allotria tritici* Fitch, and *Allotria avenæ* Fitch. Of the Coccinellidæ he mentions *Hippodamia parenthesis* Say; *Coccinella 5-notata* Kirby, and *Coccinella 9-notata* Hbst.

The only species bred by me from the grain aphis thus far, though in considerable numbers, is *Aphidius nigriceps* Ashmead.

There were also bred by me a number of specimens of *Syrphus americanus* Wied., the larvæ of which prey voraciously upon the lice.

The following original specimens, preserved by Fitch and bearing his identical numbers and names, as found in his notes, are: 4987, var. *pallidicornis;* 4988, *triseriata;* 4990, *obsoleta;* 4992, *bicincta;* 4993, *nigricollis;* 4994, *tergata;* 4995, *thoracica;* 4997, *nigriventris;* 5000, *fulviventris*, and 4991, without a name attached, which is probably identical with his variety *immaculata.* None of the following numbers of *A. mali*, mentioned in his notes, were found: 1125, 1126, 4987, 5004, 5548, 5549, 11603 and 11604, ♂, 11605 and 11606, ♀, nor 11844–11853. One specimen, a male, marked by Fitch with the printed number 839, is preserved in the State Cabinet of Natural History of New York, at Albany, N. Y.

Of *Aphis prunifoliæ* Fitch, the following specimens, mentioned in his notes, are still preserved: *a*, *d*, *e*, *f*, *g;* while *b*, *c*, *h*, and numbers 3772–3783 are lost.

Of *Aphis avenæ* Fitch, but three specimens were found; two specimens bore No. 15237 and the other one 15238, while 15239 is lost.

THE ENGLISH GRAIN LOUSE.

(*Macrosiphum granaria* Buckton.—Fig. 2.)

Siphonophora Koch, Pflanzenläuse, p. 150, 1857.
Macrosiphum Passerini, Gli Afidi, p. 27, 1860.
Nectarophora Oestlund, Aphididæ of Minnesota, p. 78, 1887.

In accordance with priority, the generic term Siphonophora, as adopted by Koch, had already been preoccupied by Eschscholtz and described by him in "Syst. d. Acaleph." in 1829, though, without knowing this fact, it was again applied by Brandt, "Bull. Acad. St. Petersburg," in 1836, for a genus belonging to the Myriapoda. Oestlund, recognizing the preoccupation of Siphonophora, substituted for it (Aphididæ of Minnesota, p. 78, 1887) the name Nectarophora, overlooking the fact that Nectarophora was antedated by Macrosiphum *Pass.* (Gli Afidi, p. 27, 1860), a generic term, unfortunately, adopted by Oestlund for a species with long and clavate nectaries, found on *Rubus strigosus*, which he named *Macrosiphum rubicola*, a generic term also adopted by Del Guercio (Afidafauna Italica, pp. 144 and

159) for a number of species agreeing with the characters of Macrosiphum Oestlund, overlooking, however, the fact that Macrosiphum was preoccupied by Passerini for a genus structurally quite different. Dr. M. H. Schoutenden was the first to observe this error, and changed Macrosiphum *Oestlund* to Nectarosiphon, in contradistinction to Macrosiphum *Passerini*.

The principal characters of this genus, as accepted by authors, are:

GENUS MACROSIPHUM *Passerini*.

Front of head deeply concave, provided with large, terminally diverging frontal tubercles or projections for supports of the antennæ. Antennæ long and filiform, as long or usually much longer than to the end of the body or tail, with the spur of the sixth joint very long and bristle-like. Nectaries very long, cylindrical, tapering, and frequently projecting beyond the tail. Tail long, slender, more or less distinctly contracted near its base, curved upward. Legs long and slender. Wings large, the third discoidal vein with two forks; stigma rather long, narrow, elongate lanceolate. The majority of the species are large and frequent the foliage of weeds, cultivated plants, and grasses.

Macrosiphum granaria Buckton.

Siphonophora granaria Buckton, Monogr. of British Aphides, vol. 1, p. 114, 1876.
Siphonophora avenæ Thomas (in part), Eighth Rept. Nox. and Benef. Insects of Ill., p. 51, 1879.

With regard to this species much uncertainty has existed. Buckton was the first to introduce this name in his writings on English Aphides, on the supposition that the insect in his hands at the time was identical with that treated of by Kirby and Curtis under the name of *Aphis granaria*, concluding also that *A. avenæ* Fab., *hordei* Kyber, *cerealis* Kalt., and *Siph. cerealis* Koch were all of them the same species. After examining, however, the extremely short and in every detail insufficient description of *A. granaria* by Kirby (Linn. Soc., 4, p. 238, 1798), I doubt very much that the species mentioned by Kirby and Curtis under the above name is identical with the one described by Buckton, but believe that the species treated of by them was the genuine *Aphis avenæ* Fab., and, while investigating this matter, found that a description of *A. hordei* was never published and that the name of it was simply suggested by Kyber (Germar's Mag. d. Entomologie, vol. 1, pt. 2, p. 11, 1815), with a footnote to the effect that he intended to describe the species later on. It was surely not identical with *A. cerealis* Kalt. and Koch, which I have known for some years to exist in this country. Buckton, while describing his *granaria*, seems to have mainly depended on the superficial description of the species by Curtis (Farm Insects, pp. 287–290, figs. 9, 10, 11, and Pl. J, figs. 10, 11, 13, 1860, the figures of which are absolutely unreliable). As far as the description of *avenæ* is concerned, I am confident that it does not belong to Siphonophora *Koch*, since the frontal tubercles so characteristic of Siphonophora are wanting. Curtis states that the antennæ are inserted in front of the face, close to the inner margin of the eyes, which character alone would remove it from Siphonophora and bring it nearer to genera with rudimentary frontal tubercles, more or less closely related to Aphis. I should, therefore, not be surprised if future studies should disclose the fact that the species described by Curtis is identical with *Siphocoryne* (*Aphis*) *avenæ* Fab. Buckton was apparently misled by the colored figure of a migrant on Pl. J, on which a number of spots on the abdomen are represented which have not been mentioned in the description, which plainly indicates that he described one and figured quite a different species found on grain at the same time. At any rate, the first substantial description and illustration of the present species must be credited to Buckton.

As to the *Siphonophora avenæ*, as described by Thomas, in which he includes *granaria*, *cerealis*, and *hordei*, I will say that he is very much mistaken. On page 52, and partly on page 53 of his report, Thomas simply reproduces the description of the true *Siphocoryne* (*Aphis*) *avenæ*, as described by Fitch in his sixth report (p. 95, etc.), which he considered, without a doubt, as being identical with a species found by him on grain, whereas his description of the insect (p. 53) tallies well with *Siphonophora granaria* as described by Buckton.

Until quite recently I considered the species treated of by Thomas as being identical with *A. avenæ* Fab., until a careful examination of specimens found by me on oats at Stettin, Prussia, July 26, 1898, convinced me that the species found then was identical with the one described by Buckton and agreeing also with the short description of *avenæ* Thomas (Eighth Report Nox. and Benef. Insects of Ill., p. 53, 1879), though not with the species described by Fitch under the name of *A. avenæ*.

Prior to that date and since then the same species had been received by the Department from Concord, N. C.—May 25, 1882, found infesting the ears of wheat. During December, 1888, it was found on wheat at Lafayette, Ind. In 1889 it was found on wheat at Washington, D. C., and during August of the same year at Lafayette, Ind., on oats. In June, 1897, it was found on wheat and grass at Washington, D. C., and in May, 1898, on wild rye (*Elymus virginicus*) growing in Virginia near the shore of the Potomac. During the month of June, 1900, it was found at Milford, Del., on wheat and rye, and in various localities in Kansas, where it sometimes proved to be very abundant and destructive to wheat and oats, and on heads of wheat at Macomb, Ill.; it was also reported as doing much damage to wheat at Northville, N. Dak. During April and May of 1901 it was reported as doing much damage to wheat from Adonia, Farmville, Shirley, and Spring Garden, Va., while, lastly, it was found to be very numerous on young volunteer wheat in the District of Columbia.

The list of grains and grasses on which it has thus far been observed is rather small, though there can be no doubt that it will eventually be found to subsist on many other grasses and possibly also on some weeds or other cultivated plants.

That it must have existed in this country for a considerable length of time seems evident from the fact that its distribution has spread from Virginia to North Dakota, and that it will gradually be found in all the intervening States both north and south, as well as in the Western States or wherever wheat or other grains are grown, where occasionally it may prove a serious pest.

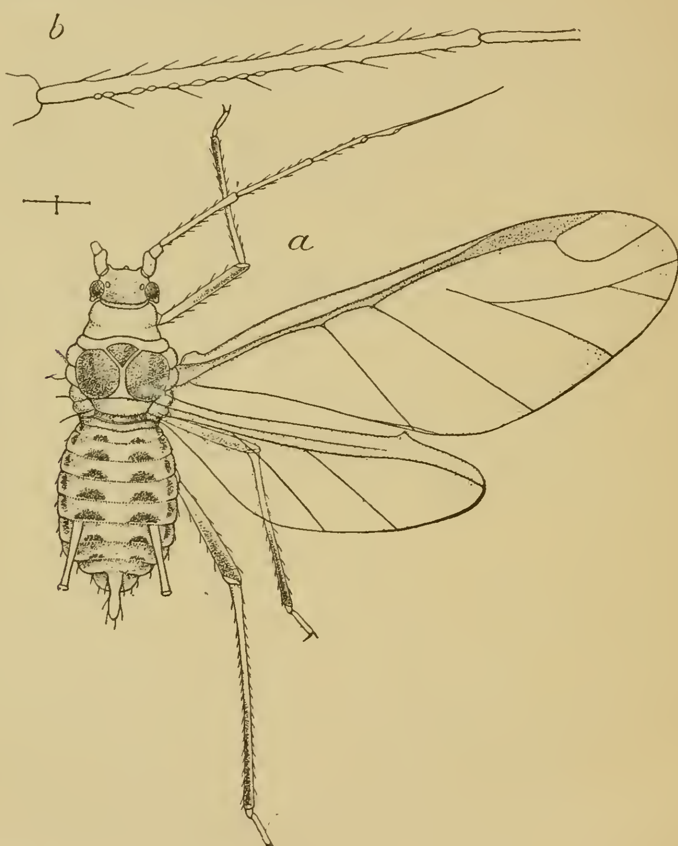

FIG. 2.—*Macrosiphum granaria* Buckton: *a*, migratory female; *b*, third antennal joint of same, all greatly enlarged (original).

DESCRIPTION OF THE SPECIES.

Apterous female.—Length 2.4 to 2.8^{mm}; fusiform, broadest near the base of the abdomen. Frontal tubercles large, diverging at the apex, as usual, in this genus; antennæ bristle-shaped, as long or slightly longer than the abdomen; joint six, including the spur, longer than joint three; generally there are one or two small, circular and projecting sensoria near the base of the third joint; all of the joints are very sparsely beset with short and stiff bristles which are rarely slightly clavate. The nectaries are long and reach beyond the tip of the abdomen, though rarely beyond the tip of the tail; they are cylindrical, tapering, becoming again slightly stouter toward the end. The tail is rather long and stout, curved upward, and about two-thirds the length of the nectaries, lanceolate, and more or less distinctly constricted about the middle; it is densely covered with acute, minute points and furnished each side of its terminal half with three, backward-curved, long bristles. The legs are long and provided with short, stiff, and simple hairs.

The color of the apterous female is yellowish-green, often slightly pruinose; frequently darker toward the end of the body; the head varying from yellow to brownish-yellow. The eyes are red to brown, while the tail varies from white to a distinct yellow. The antennæ, as a rule, are black, though sometimes the first joint may be yellow or the first three joints dusky. The terminal half or more of the femora, apex of the tibiæ, the tarsi, and the nectaries brown to black; the rest of the leg is yellow. The body is frequently marked with a brownish puncture or spot each side of the prothorax; sometimes there is a narrow dusky or black line, composed of minute spots, each side of the mesothorax and a dorso-lateral row of about five linear or rounded, blackish or dusky spots each side of the abdomen, which sometimes are extremely faint or even wanting. Occasionally there are also two additional small black or dusky spots between the nectaries. Lateral spots in front of nectaries black.

Winged migrant.—Expanse of wings 9 to 9.4^{mm}; length of body 1.4 to 2.6^{mm}. Antennæ long, generally about one-third longer than the body; the third joint about one-third shorter than the sixth and provided along its exterior or posterior edge with from six to eleven more or less elevated, round sensoria along its basal third. The hairs of the various joints are similar to those of the apterous female, though sometimes one or the other may be distinctly clavate. The nectaries, tail, and legs in general appearance and size are very similar to those of the apterous form. The wings are almost twice the length of the body, while the venation corresponds very much to that of Aphis.

Color yellowish-green to green; the mesothorax yellow and its lobes brown to black. Sometimes a small, oblique, dusky, subdorsal spot and a transverse pale-dusky band may be observed on the prothorax. Head brown or brownish-yellow; eyes red to brown. Antennæ black, the first joint sometimes brownish-yellow externally. Nectaries black, the tail yellowish or greenish-yellow; sternal plate and lateral spot in front of wings black. The abdomen is marked with four or five small, transverse, blackish dorso-lateral spots and four black lateral spots in front of nectaries; the coloration of the legs is similar to that of the apterous female. Wings clear, the costa dusky, and the subcosta yellow; stigma yellowish, its inner margin dusky; veins yellowish-brown, changing to black toward the end.

In order to distinguish this species, besides the maculations of the abdomen, from near related species infesting grains and grasses, I have adopted the rule of measuring the comparative length of the antennal joints, the nectaries, and the last fork of the wings by tenths, with the accompanying result of variation:

Joint 3, variation between 19 and 29.
Joint 4, variation between 13 and 20.
Joint 5, variation between 11 and 17.
Joint 6, variation between 24 and 34.
Nectaries, variation between 11 and 16.
Last fork, variation between 22 and 36.

The sexual generation or the eggs have thus far not been observed.

Of their natural enemies or parasites none have been observed, though there can be no doubt that various species of ladybirds as well as the larvæ of Chrysopids and Syrphids will prey upon them whenever they become sufficiently numerous to attract their attention.

THE GERMAN GRAIN LOUSE.

(*Macrosiphum cerealis* Kalt.—Fig. 3.)

Aphis cerealis Kalt., Monog. d. Pflanzenläuse, p. 16, 1843.
Siphonophora cerealis Koch, Pflanzenläuse, p. 86, 1857.

This species was first described by Dr. J. H. Kaltenbach (Monogr. der Pflanzenläuse, p. 16, 1843). At the time he considered it as being identical with *Aphis hordei* Kyber, which, however, had never been described.

As food plants the following grains and grasses are mentioned by him: Wheat (*Triticum sativum*), rye (*Secale cereale*), oat (*Avena fatua* and *strigosa*), barley (*Hordeum murinum*), chess (*Bromus mollis* and *secalinus*), orchard grass (*Dactylis glomerata*), velvet grass (*Holcus lanatus*), and meadow grass (Poa), feeding on the ears, the racemes, the petiole, and occasionally in small colonies on the leaves of grains and grasses, on the former of which, during July and August, they may frequently be observed in enormous numbers.

Buckton (Monog. of Brit. Aphides, vol. 1, p. 114, 1876), as well as Thomas (Eighth Rept. Nox. and Benef. Insects of Ill., p. 51, 1879), make it a synonym of *granaria*, and the latter author considers it also a synonym of *Aphis avenæ* Fab., neither of them recognizing, however, the characters by which it may be separated from either of them; since then, nobody, at least in this country, appears to have taken the trouble to separate the species referred to, notwithstanding that the range of this species appears to be as large as that of the other grain-inhabiting Aphides.

That both *granaria* and *cerealis* are likely to be considered as but one species is very obvious, since both are of about the same size and coloration and may frequently be found intermingled on the same plant, though the maculation of the abdomen of *granaria* is absent in *cerealis*, in which the antennal joints and the nectaries are also constantly shorter. Divided by tenths, the following variations in these organs will be observed in the present species:

Antennal joint 3 varies between 18 and 27.
Antennal joint 4 varies between 13 and 21.
Antennal joint 5 varies between 11 and 17.
Antennal joint 6 varies between 24 and 37.
Nectaries vary between 10 and 18.
Last fork varies between 13 and 22.

The above table, compared with that of *granaria*, shows that, as a rule, all of the measured parts are shorter than those of the species treated of before.

Specimens of this species were first discovered in small numbers in June, 1884, on wheat at Cabin John Bridge, Md., while during the same month, after harvesting of the wheat, it was found by me to be quite plentiful on rye and oat near Washington, D. C., and among them many of the winged insects, mainly stationed on the petioles and green seed capsules, which had become more or less discolored on that account. Whereas the majority of larvæ were found on the under side of the leaves, none were observed on the stems or roots. At the same time and in the same field they were also found infesting the ears and leaves of *Agrostis vulgaris*, *Bromus secalinus*, and *Dactylis glomerata* growing between or near the grain. During September of 1884 migratory females found on wheat were received from Oxford, Ind. As an illustration of how far certain species of aphides may be distributed by currents of air, it may be worth while to mention the fact that a number of migrants of this species were dipped up from the surface of the Alantic Ocean 94 statute miles from the nearest land, in the neighborhood of Nova Scotia, July 3, 1887, by the Fish Commission steamer Grampus. During November of the same year the species was found breeding on oat at Washington, D. C. In May, 1889, it was found on oat at Paxton and on wheat at Pleasantville, Ind., while at the same time it was reported as being very plentiful on wheat at Shiloh Hill, Ill. During June of the same year it was reported as being very abundant on wheat and oat at Glendale and Columbus, Ohio, and Vincennes, Ind., and from Selkirk, Mich., on wheat and rye, at which time it was also found to be very abundant on oat at Highlands, N. C. In August it was found on oat at Ottawa, Canada, and in October on clover growing among the dry stubble of wheat at Washington, D. C. In January, 1890, specimens were discovered on wheat in Indiana and at Liberty, Va., covering the plants and killing large numbers of them. In May of the same year they were found on rye at Landisburg, Pa., while from Trenton, Morristown, and Camden, N. J., the report came that they covered the wheat and rye and were doing much damage. During June of 1890 they were reported from Storrs, Conn., Lunenburg, Pa., New Harmony, Ind., Milton, Ky., and Larue, Ark., as ruining the wheat and oat crop. In June and July of 1891 the species was observed on wheat at Millville and McGregor, Iowa, and Nashville, Tenn. The species was also found in May of 1892 on wheat at Columbus, Ohio; in November on *Setaria viridis* at Washington, D. C.; in June and July of 1894 on timothy and wild rye in Virginia, opposite Washington, and in September on the ears of oat at Shelton, Mont. Lastly, they were reported as doing much damage to the ears of wheat from Brookings, S. Dak., since which time nothing has been heard of the species from any locality.

The food plants on which, thus far, it has been observed in this country are:

Wheat (*Triticum vulgare*), rye (*Secale cereale*), wild rye (*Elymus virginicus*), oat (*Avena sativa*), meadow grass (*Poa pratense*), green foxtail (*Setaria viridis*), red top (*Agrostis vulgaris*), cheat (*Bromus secalinus*), orchard grass (*Dactylis glomerata*), and red clover (*Trifolium pratense*).

Its range thus far has been found to cover most of the northern States, including Canada, east of the Mississippi, but having gradually spread beyond that border as far west as Montana and South Dakota, and may soon be expected to make its appearance along the Pacific slope.

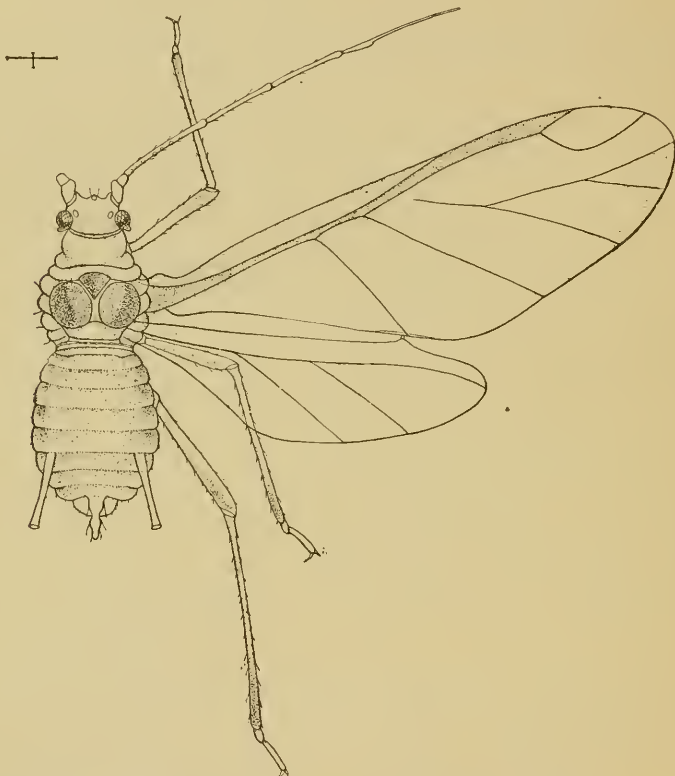

FIG. 3.—*Macrosiphum cerealis* Kalt.: migratory female; greatly enlarged (original).

DESCRIPTION OF THE SPECIES.

Apterous female.—Length of body 2 to 2.6^{mm}; broadest about the middle of the abdomen, tapering gradually toward the head and more rapidly posteriorly. Antennæ as long or slightly longer than the body; third joint shorter than the sixth and generally provided near the base with one or two small, circular, and projecting sensoria; all of the hairs small and simple or but slightly clavate. The legs are long and their hairs short, stiff, and simple. The nectaries, as usual, are tapering and reach about to the end of the abdomen. Tail long, curved upward, and almost of the length of the nectaries; it is somewhat constricted about its basal third; its terminal section elongate lanceolate; the surface is densely covered with minute, acute spines and each side provided with three backward-curved bristles. General color a somewhat polished green with a yellowish tinge along the dorsum and with a few irregular darker green markings. The head is rather dark yellow and the antennæ black with the two basal joints brownish or somewhat dusky. Eyes dark brown. Nectaries black, the tail dirty yellowish. Terminal half of femora black, the basal part pale greenish or yellowish; tibiæ dirty yellowish, their apex and the tarsi black.

Winged migrant.—Length of body 2 to 2.4^{mm}; expanse of wings 7 to 8.2^{mm}. Antennæ longer than the body, reaching to or beyond the tip of the tail; joint 3 shorter than the sixth and provided with 4 to 12 circular and elevated sensoria along the basal half. Hairs minute, sparse, and simple. Nectaries as usual, reaching slightly beyond the end of the body, though not beyond the tip of the tail, and about one-third longer than the tail.

Color of the abdomen green or yellowish green, the median line generally of a darker shade. Head light brown or pale dusky; eyes reddish to dark brown; ocelli clear, with the inner margin black. Prothorax greenish yellow and frequently marked each side with a dusky impression of three more or less distinct, dusky, longitudinal stripes. The mesothorax and metathorax are generally yellow, with the lobes, the sternal plate, and lateral spot in front of anterior wings brown or, rarely, black. Antennæ and nectaries black, the two basal joints of the antennæ sometimes dusky. Tail either colorless, pail greenish, or almost yellow. Legs yellow, the terminal third of the femora, apex of the tibiæ, and the tarsi black. Wings colorless, the subcosta and base of front wings yellow or greenish yellow. Stigma yellowish or pale dusky. Costa and veins brown to black.

The sexual generation has not been observed.

Of the enemies and parasites preying on this species which have been observed by the writer, the following may be mentioned:

The true parasites, bred from this species are: *Aphidius avenaphis* Fitch and *Aphidius obscuripes* Ashm., *Lygocerus niger* Howard and *Asaphes vulgaris* Walker; while the enemies observed to feed upon this plant-louse are the following ladybirds and their larvæ: *Megilla maculata* DeG., *Hippodamia convergens* Guer., *glacialis* Fab., *13-punctata* Linn., and *Coccinella 9-notata* Hbst.; also larvæ of the following Syrphus-flies: *Syrphus americanus* Wied., *Xanthogramma emarginata* Say, *Allograpta obliqua* Say, and *Sphærophoria cylindrica* Say; specimens were also bred of two small Muscid flies, the larvæ of which feed on the aphides, as *Leucopis nigricornis* Egger and *Leucopis simplex* Loew.

THE CLOVER PLANT-LOUSE.

(*Macrosiphum trifolii* n. sp.—Fig. 4.)

Specimens of this new species have been occasionally found at Washington, D. C., since the fall of 1889 until the summer of 1892, on wheat (*Triticum vulgare*); and on oats (*Avena sativa*), at Wooster, Ohio, which, at the time, on account of their food plant and general appearance, I considered to be but a variation of the (so-called) *Siphonophora avenæ* Thomas. During July, 1892, I found it also feeding on the stems of red clover (*Trifolium pratense*), and during November of the same year on the petioles and leaves of strawberries, at which time I concluded them to be different from the other grain lice though possibly related to, but quite different from, *Siphonophora fragariæ* Koch. The following year it was again found on strawberries during November at Washington and very numerous in June, 1894, on the stems of red clover and on the stems of the common sow-thistle (*Sonchus oleraceus*). During the same month this species was also observed to be very common on red clover at Cadet, Mo., and on the leaves of dandelion (*Taraxacum dens-leonis*) at Washington. In

FIG. 4.—*Macrosiphum trifolii* Perg., n. sp.: migratory female; much enlarged (original).

April, 1900, it was reported as being very numerous on red clover at Charlottesville, Va., and in June on oat at Wooster, Ohio.

While investigating the specimens found on strawberries it occurred to me that they might possibly be identical with the species briefly described by Riley, under the name of *Siphonophora fragariæ*, var. *immaculata*, in the Rural World, for December, 1875, found on this plant at Kansas City, Mo.; but, after an examination of the few poorly preserved specimens, I found them to be different, and, since it does not agree with any of the green species known to me, I have concluded to describe it as new, particularly as it may occasionally prove to become very injurious to grain.

DESCRIPTION OF THE SPECIES.

Apterous female.—Length of body 2.4 to 3^{mm}. Antennæ slender, reaching to or beyond the tip of the tail; third joint shorter than the sixth, provided with one to three small circular and elevated sensoria; hairs minute, sparse, and simple. Nectaries very long and slender and longer than the third antennal joint; much thinner at the apex than at the base, curved upward and reaching to or beyond the tip of the tail; tail long, tapering, more than half the length of the nectaries, densely spiny, and provided each side with four backward-curved hairs. Color, green or yellowish green, and frequently slighly pruinous, most densely so on the head and incisures of the body beneath, giving these parts a whitish cast; the median line of the body is generally of a darker green. The eyes are brown. The antennæ of the fully mature specimens are black, with the two basal joints more or less distinctly yellowish; in younger specimens they appear yellowish, with the apex of joints three to five and the last one black. The nectaries are usually yellowish or slightly dusky, changing to black toward the apex and greenish toward the base. Tail pale greenish or yellowish. Legs pale brownish-yellow, base of femora greenish; apex of tibiæ and the tarsi black.

Migratory female.—Length of body 2 to 2.4 ^{mm}; expanse of wings 8.4 to 9 ^{mm}. Antennæ slender and much longer than the body, the third joint much shorter than the sixth; the sensoria of the third joint are much more numerous than in that of the other two species found on grain, covering about three-fourths of the posterior edge of its base and ranging between 13 and 18 or more. The hairs of the antennæ are also longer and generally simple, though sometimes also faintly clavate. The nectaries are very long and slender, but slightly stoutest at base, reaching far beyond the tip of the tail and at least as long as the third antennal joint. The tail is of the same shape as usual in this genus and but slightly over one-third the length of the nectaries, usually densely covered with minute sharp spines and bordered each side by four slender bristles. The venation of the wings is as usual, though the terminal fork is longer than in the other two species. The general color is yellowish-green, the median line of the abdomen darker, though many of the spots wanting. The head and thoracic lobes are yellow or brownish-yellow. Eyes brown to black; ocelli clear, bordered with black. Antennæ black, the two basal joints and base of the third either green, brownish-yellow or dusky. Occasionally there are two black spots at the posterior edge of the metathorax and a black border on the scutellum. Femora green on basal half or more, changing gradually to yellow, brown and black toward the apex; tibiæ brownish yellow with base and apex black. Nectaries dusky to black and greenish at base. Tail green or slightly dusky. Wings colorless, their base and subcosta faintly greenish. Stigma pale grayish-green, the veins black.

Variations by tenths of the comparative length of the antennal joints, etc., are as follows:

Joint 3, 28 to 35.
Joint 4, 23 to 30.
Joint 5, 21 to 25.
Joint 6, 38 to 43.
Nectaries, 28 to 31.
Third fork, 22 to 32.

Compared with the other two species it will be seen that the proportions of these organs are much the largest, those of *cerealis* being the smallest.

The sexual generation or their enemies have not been observed.

THE CHESTNUT WEEVILS, WITH NOTES ON OTHER NUT-FEEDING SPECIES.

By F. H. Chittenden.

INTRODUCTORY.

The public is quite familiar, and disagreeably so, with "wormy" chestnuts. The grower who depends on the cultivation of chestnuts for a livelihood, or a portion thereof, knows "how the worm gets in the nut," and if he be a good observer he knows that it develops from a minute egg deposited by a long-legged, yellow or ochre-colored weevil, with a fine, slender snout longer than the body. From eggs so or deposited hatch the disgusting "worms." Thus much is known to the chestnut grower; also to many it is known that there are at least two species of the weevil. It was not until the year 1890 that any extensive work was undertaken to determine the life habits of the various species which are concerned in injury to chestnuts, hazelnuts, hickory nuts, and acorns. In that year Dr. John Hamilton[a] published an excellent eight-page account of the habits of our best-known species, eight in number.[b]

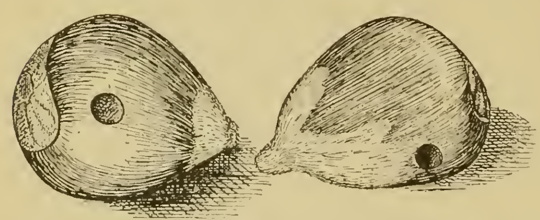

Fig. 5.—Chestnuts showing exit holes of chestnut weevil larvæ, enlarged one-fourth (original).

The economic side of the question has received considerable notice in articles by Messrs. Gerald McCarthy,[c] J. B. Smith,[d] and J. A. Lintner.[e] The article by the first-mentioned author is of considerable value, as it contains extracts from experienced growers of chestnuts, fifteen persons in all; and that of the last writer is especially useful because of the full bibliography presented.

For many years, and particularly within the past three, numerous complaints have been made of damage by these pests, and frequent appeals for better means of controlling them are made.

The larvæ, grubs, or "worms" as they are more commonly called, develop with the nuts so that those which first attain maturity are ready to leave the nuts nearly as soon as gathered. Others remain

[a] Balaninus: Its Food Habits, Can. Entom. (Vol. XXII, pp. 1–8).

[b] Nine or ten other species have been described, but we know little of their habits, and they therefore need not be considered in the present article. (See Capt. T. L. Casey, Annals New York Acad. Sciences, Vol. IX, 1897, pp. 655–664.)

[c] Bul. 105, N. C. Agr. Expt. Sta., 1894, pp. 267–272.

[d] Rept. N. J. Agr. Expt. Sta., 1895 (1894), pp. 481–485.

[e] Twelfth Rept. N. Y. St. Ent. 1896 (1897), pp. 267–272. It should be mentioned, that certain notes by the writer (Ent. Amer., Vol. VI, p. 172) were not included.

until long afterwards, and not infrequently it happens that when nuts are stored in barrels, boxes, or similar receptacles, some nuts which were apparently sound when placed therein, are found with one or more holes in their shells, while the disgusting grubs can be seen in great numbers at the bottoms of the receptacles. The size of the exit holes varies from one-sixteenth to one-eighth inch, the smallest ones doubtless being made by a single larva of the smaller species of weevil, and the larger by the larger weevil, or perhaps by several of the smaller species. Injury varies according to the number of larvæ present and the size of the nut, as will presently be more fully explained (see fig. 5.)

During comparatively recent years the culture of chestnuts has assumed considerable proportions, especially in the States of Pennsylvania, New Jersey, Maryland, and Delaware, and has taken a new impetus since the extensive introduction and development of Japanese and European varieties. These are grafted on American seedlings or native stocks, and thus many nearly valueless trees on equally unpromising soil are converted into sources of profit greater by far than if the same land were planted with other crops which could be grown. In short, were it not for the "worms" and "blights," chestnut growing might develop into a most profitable industry in regions adapted to it.

RECENT INJURIES.

During 1903 we received, among other reports of losses by nut weevils, two from Mount Joy, Pa., which are in brief as follows:

April 20 it was reported that chestnuts were grown very extensively in that vicinity, one firm having as many as 800 acres under cultivation. The chinquapin weevil was known to our informant, who identified it among others of its genus, but subsequently it was learned by the receipt of specimens that the chestnut weevil was also present. He noticed that they appeared about the middle of July, remaining in the orchards until the first of September. He calculated that usually one in every four nuts was infested, and observed as many as thirty young grubs in single large nuts of the Paragon variety.

In November our second correspondent corroborated the above statements, reporting that one firm had recently lost from 15 to 20 per cent of their chestnut crop of 800 acres from the ravages of weevils. From 75,000 to 80,000 grafts were growing there. Paragon nuts containing both forms of weevils were received, with report that from forty to fifty grubs were found in one nut, indicating the astonishing prevalence of the insects in that region. In such nuts every bit of meat was consumed, and some of the weaker weevils were starved. In the smaller nuts, one or two worms to a nut was the rule. Native nuts adjoining the orchard under cultivation were admitted to be neglected.

ESTIMATES OF LOSSES.

A fair estimate of the total damage done annually by weevils to chestnuts grown for market in all portions of the United States would probably fall little short of 20 or 25 per cent, while in some years the percentage would exceed that, running as high as 40 or 50 per cent. Growers in some localities report no damage, others place their loss as low as 5 or 10 per cent, while instances are cited of whole crops being destroyed. A loss of 10 per cent, as with many other crops, although existent, is frequently passed over unnoticed. The amount of loss is dependent on locality, season, and to a certain extent perhaps on the variety of chestnuts grown. The greatest damage is usually incurred in regions where chestnuts have grown wild for many years, and the least in localities where there are no wild chestnuts or chinquapins and the nuts are grown only for market and carefully gathered. The greatest damage, from available sources of information, appears to be done in Massachusetts, Pennsylvania, New Jersey, New York (in the vicinity of New York City), Delaware, Maryland, Virginia, Tennessee, and North Carolina.

In Georgia Spanish and Japanese varieties have been cultivated for years without attack by weevils being noticed. In New Jersey 50 per cent of the same varieties have been ruined. One grower in Missouri has reported no damage to 50 trees of an American variety about 18 years old, while another, at South Haven, Mich., has reported no injury for a period of three or four years to Japanese and Spanish chestnuts grown there, while from 5 to 20 per cent of the crop of native chestnuts was annually destroyed. The same correspondent reports having received 4 pounds of chinquapins from Tennessee, all infested. A Delaware grower has reported every nut on a single tree completely destroyed by the "worms," and Dr. J. B. Smith the nearly complete destruction of the chestnut crop of New Jersey for 1893.

THE SPECIES OF CHESTNUT WEEVILS.

The weevils which we know to depredate on chestnuts are two in number, the chinquapin weevil, *Balaninus proboscideus* Fab., and the chestnut weevil, *B. rectus* Say. Like all other species of the genus they have extremely long, slender beaks or snouts, nearly as fine as a horsehair, and in these species considerably longer than the body in the female. By means of this long snout the female is able to penetrate the thick burr of the chestnut with its long spines and to cut out with the minute and sharp mandibles at the tip a little hole for the deposition of her eggs. These are deposited, by means of a long ovipositor, through the husk, to the growing nut. The two species resemble each other greatly in color and in markings, the general color of both being golden yellow above (generally described as ochraceous or even clay yellow), and a little paler on the lower surface. The disk of the thorax is dark brown, with a wide bright band each side, and the elytra are ornamented with rich brown markings of variable size and extent.

THE CHINQUAPIN WEEVIL.

(*Balaninus proboscideus* Fab.)

The chinquapin weevil or larger chestnut weevil (fig. 6) is considerably the larger and more robust, while the female rostrum or snout, although proportionately of about the same length, is a little more prominent because less curved, the curvature being toward the tip, and more widened at the base. The first joint of the antenna proper (omitting the scape or long joint nearest the head) is shorter than the second, and the mesosternum is less convex. The body measures from one-third to nearly one-half of an inch in length, and the snout of the female is sometimes five-eighths of an inch long. That of the male is nearly as long as the elytra.

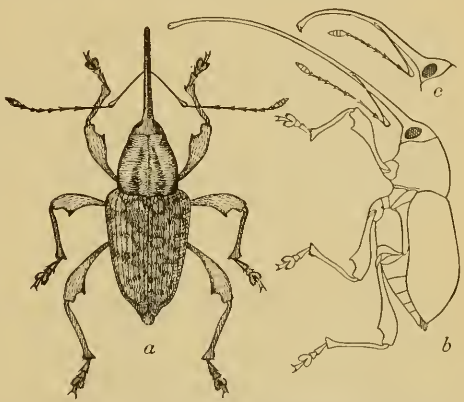

FIG. 6.—Chinquapin weevil (*Balaninus proboscideus*): *a*, female beetle; *b*, same in outline from side; *c*, head, rostrum and antenna of male, three times natural size (original).

Occasional individuals lack the darker markings, some being paler while others are darker, even reddish. The ground color, as may be seen in abraded specimens, is really black, and the color is due to scales very similar to those of butterflies and moths.

The egg of this species, or, for that matter, of the genus, has apparently escaped observation, since no description has been made of it.

The larva of *proboscideus* (fig. 7, *a*) is slightly different from the normal curculionid in form. It is milk white, robust, fully three times as long as wide, the upper surface rounded and convex; the sides are somewhat flattened, and the lower surface is much flattened when the larva is at rest on a smooth surface. The entire surface is very strongly wrinkled transversely, and there are a very few short hairs scattered sparsely over the different segments. The spiracles are irregularly rounded and rather prominent. The head (fig. 7, *b*) is nearly circular or slightly longer than wide, pale yellowish brown, marked with the usual inverted Y-spot, and the mouth parts are mostly black or very dark brown. The first thoracic segment has a narrow pale yellow cervical plate divided at the middle, and nearly twice as wide as the head. The head is about one-fourth as wide as the widest portion of the body. The fully developed larva in ordinary resting position measures nearly half an inch, while extended it measures a full half inch.

Although, like most Curculionidæ, the larva has no true legs, it crawls with comparative ease, though slowly, by means of the flattened lower surface, being aided somewhat by the transverse wrinkles. The hairs are so short as to be of little or no apparent assistance in locomotion.

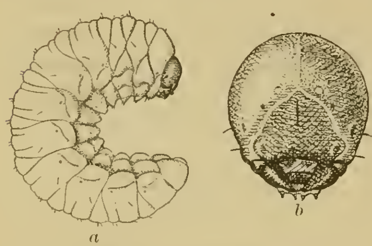

FIG. 7.—*Balaninus proboscideus:* larva, about four times enlarged, at left; head much enlarged, at right (original).

The pupa has not been seen by the writer.

The occurrence of the chinquapin weevil has been noted at Providence, R. I.; in the neighborhood of New York City; Moorestown, Woodside, Orange Mountains, N. J.; at State College, Allegheny, Jeannette, Mount Joy, Sylvania, Princetown, and Eastmont, Pa.; Newark, Del.; Baltimore, Md.; Virginia; West Virginia; Washington, D. C.; Cincinnati and Newark, Ohio; Illinois; St. Louis, Mo.; Sharpstown, Ind.; Clarkville, Tenn., and Rosedale, Kans.

THE CHESTNUT WEEVIL.

(*Balaninus rectus* Say)

The lesser chestnut weevil (fig. 8) has the scape of the antenna longer than in *proboscideus* and the first joint longer than the second. In the female the rostrum is strongly curved, the thorax is longer than wide, and the elytra are strongly acuminate apically. The tooth with which the femora or thighs are armed is small, with the entering angle rounded. The average length of the body is about one-half of an inch, but the size varies, as in all of these insects.

FIG. 8.—Chestnut weevil (*Balaninus rectus*): *a*, female beetle; *b*, same, lateral view; *c*, head, with rostrum and antenna of male, four times natural size (original).

The distribution of these two weevils does not differ markedly, but *proboscideus* appears to be somewhat more abundant southward, while *rectus* is the more prevalent northern form. Where chestnut growing is an important industry the two species appear to be nearly equally numerous.

The chestnut weevil occurs in Canada; Mount Tom and Marion and elsewhere in Massachusetts; Penn Yan and Ithaca, N. Y., and in the neighborhood of New York City, on Long Island and Staten Island; and in neighboring portions of New Jersey, as also elsewhere throughout the latter State; Mount Joy, St. Vincent, Allegheny County, Pa.; North Carolina; Baltimore, Md.; Washington, D. C.; Pennington Gap and elsewhere in Virginia; French Creek, Harpers Ferry, Fort Pendleton, and Berkeley, W. Va.; Ohio; Retreat, N. C.

The larva, as would be supposed, is much smaller than that of the chinquapin weevil, being only a third of an inch long and about a third as wide as long. The body is milk-white and the head light brownish yellow, the ⅄-mark with a short lateral branch each side.

TIME OF APPEARANCE OF THE TWO CHESTNUT SPECIES.

Balaninus proboscideus, according to Hamilton's observations, appears at the time of the first blooming of chestnuts, and disappears when the blossoms have fallen. In his rearing experiments at Allegheny, Pa., the beetles began to issue June 25, and ceased July 12. Mr. Th. Pergande reared the beetles in the District of Columbia from August 10 to September 15. As 80 examples were reared by Hamilton and the mean temperature was nearly normal (although not so considered by Hamilton himself), these dates are approximate for regions with a climate like that of Allegheny, Pa.

Balaninus rectus was reared by Hamilton from June 28 till October 1, 95 examples having been under observation. This experience coincides somewhat closely with the writer's who has found this species in the field, although somewhat scatteringly, when chestnuts were in bloom, and reared specimens in captivity during the latter days of September which remained alive nearly a month.

From present knowledge it is evident, therefore, that *proboscideus* might be somewhat more easily controlled than *rectus*, with its much longer active period. In most other respects the two species show very close agreement as to their life history.

HIBERNATION.

The chestnut weevils, as also all related species, so far as we know, hibernate exclusively in the larval condition and in the soil. This gives a larval period of at least ten months, and some individuals (reared in confinement, it is true, but under comparatively natural conditions) pass over till another year, this being the exception, but evidently a provision of nature for the continuance of the species. In such cases the larval condition lasts nearly two years. This has been noticed by Doctor Hamilton in the case of several species, and in our own rearing jars in the case of the smaller chestnut weevil, *Balaninus rectus*.

Larvæ pass the winter at varying depths, according to the soil and the degree of its hardness. In a large jar, full of moderately moist sand, in which chestnut "worms" have been placed by the writer, the larvæ have penetrated to a depth of 9½ inches in a possible 10 inches. They make cells considerably larger than themselves, so that they have ample room to move about. The larger cells of *proboscideus* are half an inch long and about one-sixth of an inch in height. As a rule, the larvæ rest on their backs in a moderately curved position. Ordinarily they remain in perfect quietude even in a moderately warm temperature, but respond to stimulus.

FOOD HABITS OF SPECIES OF NUT WEEVILS.

Of the eight species of nut weevils of the genus Balaninus known to inhabit America north of Mexico, the food habits are approximately known, largely through the investigations of Dr. John Hamilton (l. c.). The following summary is given of the observed host plants:

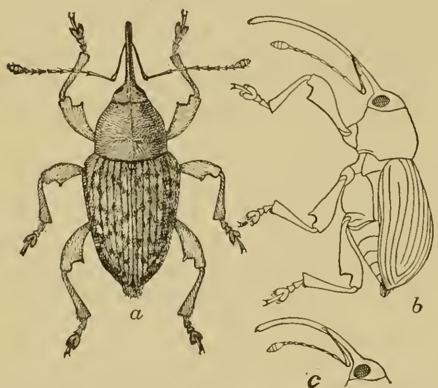

FIG. 9.—An acorn weevil, *Balaninus victoriensis*: *a*, female, dorsal view; *b*, same, lateral view; *c*, head of male, showing antenna and rostrum, four times enlarged (original).

Balaninus rectus Say, the common chestnut weevil, is nearly confined to chestnuts and chinquapins, having been reared only from these nuts, with the exception of a single lot (identified as this species) which bred from acorns from Arizona. It appears to be the only species affecting chestnuts in the extreme northern portion of the United States where Balaninus occurs.

Balaninus proboscideus Fab. (*caryatrypes* Boh.), the chinquapin weevil, depredates chiefly in chestnuts and is quite as great a pest as the preceding in some regions. It also breeds in chinquapin.

Balaninus quercus Horn affects in about equal numbers acorns of different species of biennial fruiting oaks, not being found in annuals (white and chestnut oaks). Mr. Fdk. Blanchard has reared this species from acorns of *Quercus rubra*, and the writer obtained many specimens from the same or a closely related species.

Balaninus nasicus Say prefers the acorns of the annual fruiting oaks (white and chestnut), depredating sparingly on those of biennials.

Balaninus caryæ Horn has been reared from pecans from Indiana, and has been found so abundantly on hickory as to leave no doubt that "wormy" hickory nuts are also due to the work of the same species. As a rule, however, it does much less injury to these nuts than do the others to acorns and chestnuts. Mr. Blanchard has also reared this species from shagbark hickory.

Balaninus uniformis auct. prefers the acorns of biennials, but depredates occasionally on chestnut oak. In some localities, at least during certain seasons, as, for example, at Ithaca, N. Y., this species is the most abundant, while in western Pennsylvania Hamilton found it comparatively scarce. Possibly the variation in numbers may be seasonal.

Balaninus victoriensis Chttn. n. sp.[a] is also an acorn weevil, having been collected in great numbers on oak by various collectors.

Balaninus obtusus Blanch. has been reared from hazelnuts only (Hamilton, Can. Ent., vol. XXII, p. 6). In 1891 hazelnuts were reported badly injured by this species in Iowa (Alda M. Sharp, Bul. 17, Iowa Agl. Ex. Sta., p. 450).

Balaninus confusor Ham. has been reared from the acorns of bear or scrub oak (*Quercus nana ilicifolia*), but it probably lives on the fruit of other oaks.

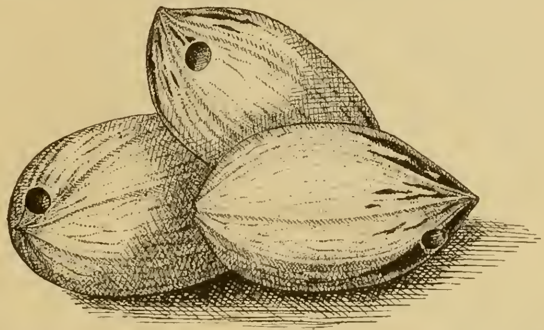

FIG. 10.—Pecan nuts showing exit hole of pecan weevil larvæ, one-third enlarged (original).

An interesting fact was brought out in the rearing of the last-mentioned species which has a bearing on the habits of the genus. A single individual was reared from a large apple oak on a species of golden rod (*Solidago nemoralis*), due to the larva of a two-winged fly, *Acinia solidaginis* Fitch (see Can. Entom. Vol. XXV, p. 310), showing the possibility of the different species developing on other than their normal food plants. In this case, as Hamilton remarks, oviposition on the gall was probably a mistake on the part of the parent beetle. Three of the larvæ were observed. It might be impossible for species with short snouts like the hazelnut weevil to oviposit in chestnuts on account of the thicker husk and longer spines, but, on the other hand, it might be possible for some other species to depredate on hazelnut in the event of absence of the normal host plant.

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[a] *Balaninus victoriensis* n. sp. (fig. 9).—With a view to lessening the confusion which has existed with reference to the name of this species, which is generally known in collections as *uniformis* Lec. or *obtusus* Blanch., the writer presents a brief analysis which, together with the illustration, will more clearly define its identity:

Body black or nearly so, covered with dense gray scale-like pubescence; elytra variously mottled with brown, slightly elevated, pubescent spots. Rostrum ♀ four-fifths as long as body (including head), moderately, nearly uniformly arcuate. Antennal joints as figured, length a little shorter. Length, 7^{mm}.; width, 3.5^{mm}. Habitat: Victoria and elsewhere in Texas. Related to *uniformis* Lec. from California, which is described as "*densissime fulvo-pubescens, concolor,*" etc. The latter is smaller. *B. obtusus* is much more robust and has a much shorter rostrum in ♀.

THE HICKORY-NUT WEEVIL.

(*Balaninus caryæ* Horn.)

Nearly every year inquiry is made in regard to the cause of the holes in hickory and pecan nuts, but during 1903 there were reports of greater injury of this nature than ever before, more particularly to pecans grown in Texas, where considerable loss was reported by Mr. Glenn W. Herrick, and in Georgia, where Mr. Wilmon Newell stated that in one locality (Thomasville) 75 per cent of the crop was a failure. A shortage was also reported near Jackson, Miss., and Mr. J. F. Jones estimated the loss of 25 per cent of the crop in the vicinity of Monticello, Fla. There is little doubt that the species of weevil involved in attack in all cases is *Balaninus caryæ* Horn, although the adult has not as yet been reared.

As this species may be destined to become one of the principal pests of the pecan orchards of the South, the accompanying illustration is furnished, together with a few words of description. The beetle (fig. 11) is quite as large as the chinquapin weevil, from which it may be distinguished, however, because of the first antennal joint being longer than the second, and in the much darker color. The ground color is dark brown, nearly black, and the scaly covering (which characterizes the chinquapin and chestnut weevils) in this species is less obvious, much darker, and hair-like. Moreover, the rostrum of the female is comparatively a little shorter, although of about of the same curvature, and less widened at the base.

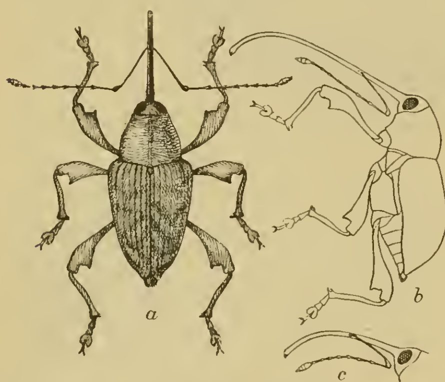

FIG. 11.—Hickory-nut weevil (*Balaninus caryæ*): *a*, female, dorsal view; *b*, same, lateral view, in outline; *c*, head with rostrum and antenna of male, about two and one-half times natural size (original).

The larva differs from that of *proboscideus* in being decidedly yellow, having the head bright red and wider than long. The cervical plate is also darker.

This species was described from Brooklyn, N. Y., in 1873 (Horn, Proc. Amer. Phil. Soc., Vol. XIII, p. 460). In the national collection are specimens from St. Vincent, Allegheny, Limerick, and elsewhere in Pennsylvania; Cincinnati, Ohio; Sharpstown, Ind.; Virginia; Iowa City, Iowa, and Holly Springs, Miss.

During January, 1904, Mr. Wilmon Newell sent a considerable number of larvæ, mostly in good condition, found in the pecan nuts. Most of the nuts, however, found at this time under trees contained holes from which the larvæ had escaped at an earlier date.

NATURAL ENEMIES.

At least one natural enemy is known of tne genus Balaninus, a braconid parasite, *Urosigalphus armatus* Ashm., which develops within the body of the larva of all the common species. A second parasitic proctotrypid, *Trichasis rufipes* Ashm., has been reared from acorns infested with *Balaninus nasicus* and *Holcocera glandulella*, and it is quite likely to be a parasite of the chestnut weevils.

METHODS OF CONTROL.

It is greatly to be regretted that no very practical remedy for nut weevils is known or can be suggested at the present day other than the early destruction of the "worms" in the nuts and observance of cooperative clean cultural and other methods, which will presently be mentioned. Before discussing these methods it may be well to preface a statement of the uselessness of ordinary measures employed in the control of similar insects.

UNSATISFACTORY METHODS.

Stomach poisons.—The peculiar structure of the mouth-parts of these insects (very minute mandibles placed at the end of a rostrum or beak as fine as horsehair and longer than the body in the females) is almost sufficient proof of itself that the adults do not feed on leaves, but depend for their sustenance on the substance of the growing nuts or inner husks, which they penetrate when making a nidus for the deposition of their eggs. The first appearing beetles, with little doubt, feed on the undeveloped very young nuts, and to a considerable extent on the juices within the husk. There is, therefore, no seeming possibility of our reaching these insects at all by means of stomach poisons, particularly as we are unable to place the insecticide where the insects would be obliged to eat enough of it to kill them.

Contact poisons.—Possibly contact poisons might have some effect, but this is also doubtful, and such frequent applications would be necessary, considering the long periods of these weevils in the adult stage—from about the middle of July to the first of September and even later—that this would not be profitable in any case. Again, there is great difficulty in applying a spray so as to reach all portions of a tree where the nuts are borne. Kerosene emulsion, sprayed on the trees at the particular time when the insects are most abundant, before they have deposited their eggs, might act to some extent as a deterrent, but this is also doubtful.

The water test of infestation.—Having serious doubts as to the efficacy of an old-fashioned test as regards the difference between "wormy" and healthy chestnuts, an experiment was made with common small chestnuts obtained from a street vender November 11. In the first place 40 per cent were obviously "wormy," and only 60 per cent apparently good. Of the apparently good nuts a number were placed in water and left for several minutes, when two sank after remaining on top, and one which had sunk rose to the surface.

Results of water test with common small chestnuts.

Nuts which rose to surface.		Nuts which remained on bottom.	
	Per cent.		*Per cent.*
Uninfested	10	In perfect condition	40
Showing minute marks only; good flavored; salable	20	Slightly injured	30
Containing full-grown grubs	10	Badly infested	20
Containing immature grubs	60	Completely filled with grubs	10

Noticeably wormy nuts as observed from the outside, and by the loss of weight after the escape of the "worms," naturally all rose when placed in water.

These experiments show that the obviously injured nuts will rise to the surface as a general rule, but the remainder require some further test than whether they will sink or float. The reader is left to his own conclusions.

DIRECT REMEDIES.

Bisulphid of carbon.—The value of bisulphid of carbon as a fumigant for nuts infested by weevils is often asked, and it would seem at first thought that its use is hardly desirable, for the reason that the larvæ or grubs are frequently so large when the nuts are harvested that purchasers would not be deceived if they took the precaution before buying of opening a few, so that there is little gain in this direction. The shell of the nut is so firm and compact that it would appear difficult for the bisulphid to penetrate and kill the larvæ. Nevertheless, a prominent grower in Pennsylvania informs me that he successfully uses bisulphid of carbon, applying it when the nuts are first harvested. In some cases the dead weevil larvæ are so small that the average person would not refuse a nut which shows only slight attack, while if these same larvæ were permitted to obtain full growth they would have nearly consumed the nut. He uses the bisulphid on one of the largest nuts grown in this country from foreign stock, and, since as many as 40 larvæ have been found by him in single nuts, one can readily see that prompt fumigation is desirable, at least in his locality. We could not claim the same for all others, because the first nuts that are brought to market in the District of Columbia are more badly infested than those purchased later; and the chinquapins, which are for sale two or three weeks earlier than the chestnuts, were, at least in 1903, very badly infested when marketed, and bisulphid would have had very little beneficial effect on them. It seems probable that this remedy would be more useful in cold localities than in warm ones, it requiring longer for the beetles to develop in the former than in the latter. An early opportunity will be taken to experiment with this remedy and growers generally are advised to do the same, taking care to use only practically air-tight receptacles and to follow the advice furnished in Farmers' Bulletin No. 145. In the meantime we can not advise its use on a large scale.

Scalding and drying.—Many growers make a practice of gathering nuts as rapidly as they fall and plunging them into boiling water long enough to kill the contained insects and not injure the nuts for market, after which they are dried before being packed and marketed. Mr. William P. Corsa, of this Department, reports success in scalding and drying the nuts in the sun before storing. Some use a sieve, which is plunged into the boiling water and quickly removed. He uses a washtub, in which he places a bushel or so of nuts, pouring enough boiling water in to come 1 or 2 inches above the nuts. Then, by stirring vigorously with a stick, the weevilly nuts will come to the surface in the same manner as do peas and beans affected by pea and bean weevils. The infested nuts are then skimmed off, and can be destroyed or fed to hogs with profit and safety, provided the animals do not have a too exclusive diet of this form of food. About five minutes in the water is a sufficient length of time. Some growers claim that salt water is preferable, the brine serving to keep the shell soft and pliable and the kernels more palatable than when not thus treated.[a]

Different methods are employed in drying. A good way is to place the nuts in the sun and agitate them occasionally by stirring or shaking in a bag until thoroughly dry, because if moisture remains unevaporated it is apt to form mildew when the nuts are packed for shipment prematurely.

It should be unnecessary to state that nuts desired for planting should not be scalded, and care should be also taken not to cook the kernels which are desired for market. Some nut growers claim that the hot-water treatment is objectionable because the nut shells lose a certain degree of polish, rendering them less desirable for market.

Some growers of chestnuts destroy the weevils by kiln drying.

Heat.—Infested nuts can be subjected to a temperature of between 125° and 150° F. without injuring them for food or for seed, and this will effect the destruction of the larvæ within.

Cold storage.—Cold storage has been employed and is successful in arresting the development of the larvæ. The appearance of the nuts is scarcely different from those not so stored, but the nuts thus treated, after becoming dry, are deficient in flavor, having, in the author's opinion, a slightly acrid and moldy taste.

[a] Note the writer's observations on this head on pp. 33 and 34.

Trap crops.—The use of varieties particularly susceptible to the weevils scattered through orchards of other varieties to attract beetles from them where they can be more readily dealt with has been suggested.[a] The reports that have been made of the liability to attack of different varieties of chestnut, however, do not, as a rule, show what varieties are in any noticeable degree immune. On this head Mr. G. H. Powell informs the writer that the Paragon, Cooper, and Ridgely are more affected by weevils than are the Japanese varieties, taken as a whole.

Jarring the trees.—This remedy was suggested by the late Doctor Lintner, because, as he says, it has been found very effectual with the plum curculio. As a matter of fact, it has not been found fully satisfactory against the plum curculio, and will be found still more difficult, not easier, in controlling the chestnut weevils. The only weevils that can be dislodged are those which happen at the moment to be disengaged, crawling from one nut to another, or in search of their mates. Like several other species of insects, these nut weevils remain paired almost continuously and while oviposition is going on. Even when the snouts of the weevils are not buried deep in the husk of a chestnut, their long and very strong legs enable them to maintain a firm hold, which the hardest jarring that the tree could stand would not dislodge. This is not mere theory, but is the experience of collectors, including Mr. Schwarz and the writer.

PREVENTIVES.

Choice of location of the orchard.—It is a matter of great importance that the locality in which chestnuts are planted or grafted on old trees be made with reference to the chances of immunity or of injurious attack by nut weevils. As may be readily inferred from what has been said in previous paragraphs, it is highly inadvisable to select for a chestnut orchard a locality in the immediate vicinity of much woodland abounding in wild chestnut and chinquapin, and perhaps oak, as the first two trees furnish the principal breeding places of these insects, and are therefore a constant menace to successful chestnut culture. To what extent, if at all, acorns furnish food for either chesnut weevil remains to be learned. A prominent chestnut grower, who has suffered considerable losses from weevils, has admitted that native chestnuts are neglected in the near vicinage of his cultivated groves. Mr. H. E. Van Deman, a practical nut grower, has directed the writer's attention to another phase of planting, which is that Paragon and other cultivated varieties are frequently grafted on native chestnuts in rocky and uneven soil, where it is not only impossible to gather a complete crop, but, what is of equal importance, the remnants can not

[a] G. Harold Powell (Bull. XLII, Del. Coll. Agr. Expt. Sta., 1898, p. 14.)

be collected. Hence, to secure clean culture, it is imperative to plant or graft only on perfectly smooth soil, first, for economic or commercial reasons, and, second, to permit the collection of all of the nuts, leaving none for the propagation of the weevils.

Careful harvesting.—One of the most feasible remedies and one that had been advised for years is to pick all of the chestnuts from the ground, taking the greatest care to leave none, and either place them in tight boxes or in barrels, where the grubs when they issue will not be able to reach the ground, or fumigate with bisulphid of carbon before shipping to market. The grubs crawl out soon after the nuts have been gathered, and as they require a considerable degree of moisture they will, if kept in closed receptacles, die without being able to reach the ground. The trouble is that enough nuts are usually left in the orchards or in the woods owned by the farmer or his neighbors to serve for the propagation of the insects for following years. In order to make this method of treatment thorough it will be necessary to secure the cooperation of neighboring landowners, not only of those who grow chestnuts for market but of all who may own woodland containing chestnut and chinquapin, which would serve for the continued propagation of the insects.[a]

The collection of remnants is no great hardship, and there are probably cases where it would be profitable to allow pigs the run of pecan orchards to destroy what nuts remain after the main crop has been harvested. In the absence of a sufficient number of the nuts it is not probable that pigs would learn to root for the grubs, if these have left the nuts and are in the ground, because of their small size and the depth to which they are able to penetrate.

It has been suggested that turkeys might be useful in destroying the chestnut weevils, but it does not seem probable that this remedy would be a safe one. If the turkeys were allowed to roam through the orchards when the burrs are first opening the beetles are also there, and if the birds attempted to devour them they would probably soon desist, owing to the strong outer shell of the beetle and its long, strong, and spiny legs. If many beetles were swallowed, they might cause the death of the turkey. Again, the hogs would probably not devour the nuts after having their mouths irritated by the spines of the chestnut husks.

Cooperation.—Although the results of the observance of clean culture on the lines that have been indicated might not be at once apparent, it can be only a matter of time, if this work is systematically carried out by all growers over a considerable territory, when infestation would be greatly decreased. An important point to ascertain is as to

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[a] It seems probable that the two chestnut weevils under consideration confine their attacks to chestnut and chinquapin, and that the acorn-feeding form from Arizona identified by Hamilton as *Balaninus rectus* will prove a different species.

how far the insects fly. Their structure indicates that they are strong fliers and capable, with favoring winds, of migrating considerable distances; but under ordinary circumstances they probably do not fly many miles at a time or in a given year.

THE ACORN MOTH.

(*Holcocera glandulella* Riley.)

In connection with a consideration of the nut weevils a few words should be said in regard to the acorn moth, a Tineid whose caterpillar develops in nuts and acorns, usually in the deserted holes of the Balaninus weevils.

The adult, or moth, is variable in color, but is more or less ashy gray, the forewings being characterized by transverse pale stripes which are not specially well shown in the illustration, but which will answer for present purposes. The moths vary in size as well as in mottling, the average expanse of the forewings being a little less than three-fourths of an inch (see fig. 12, *f*). The moth, properly mounted, looks decidedly wider than as figured. The life history of this species was long ago described by Riley in his Fourth Missouri Report (pp. 144, 145). After the weevil, which was the original inhabitant of the nut or acorn, has deserted its temporary tenement, the moth drops an egg into the already injured nut. The caterpillar hatching from this egg develops upon what has been left by the larval nut weevil, meanwhile securing the opening formed by the beetle with a covering of silk to prevent the entrance of natural enemies. Farmers who grow nuts as a side issue and who do not make a special study of the insects affecting their acorns or other nuts are often prone to the opinion that the true nut depredator is the caterpillar inclosed in these nuts after they have fallen and been left on the ground.

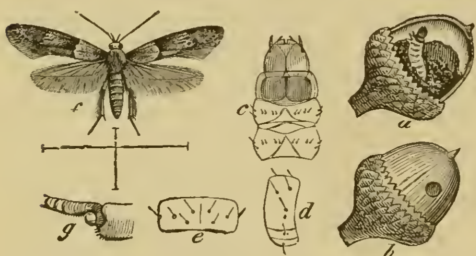


FIG. 12.—*Holcocera glandulella*: *a*, acorn showing larva at work; *b*, acorn showing closed exit hole; *c*, head and thoracic segments of larva; *d*, a lateral segment of larva; *e*, a dorsal segment; *f*, moth; *g*, base of antenna; *a*, *b*, natural size; *c*, *g*, much enlarged; *f*, slightly enlarged (after Riley).

The acorn moth caterpillar has been described as pinkish-yellowish or grayish-white. Its recognition is facilitated by the illustration, *a* showing the larva within the nut, and *b* the closed exit hole. There is no difficulty in distinguishing this caterpillar from the weevil larva or grub, as it has, like most common caterpillars, a complete complement of three pairs of legs and ten false legs. Within the nut it changes to the chrysalis stage, and the moth issues through the door. The moths appear from April until September. Whether or not this species has any other food plant than the fruit of oak has evidently never been ascertained, but it seems probable that it is one of the "husk worms" complained of by the growers of chestnuts, or that the husk worm is an allied species. It is an inhabitant of the Atlantic States, and probably extends from Canada at least to Missouri.

THE COWPEA-POD WEEVIL.

(*Chalcodermus æneus* Boh.)

By F. H. Chittenden.

For the past two years many complaints have been received from the cotton-growing regions of the South of injuries to cotton by a species of weevil known as *Chalcodermus æneus* Boh. Attempts were made by several persons of experience to ascertain whether or not the insect really did injury to the bolls or squares of cotton after the manner of the Mexican cotton boll weevil, for which it was mistaken, always,

Fig. 13.—*Chalcodermus æneus: a*, beetle; *b*, larva, in profile; *c*, larval head; *d*, pupa, all about five times enlarged except *c*, more enlarged (original).

however, with negative results. On looking over the records of the Division of Entomology extending back into 1887 we find that the insect has a natural food plant in the cowpea, particularly when this plant escapes from cultivation or grows wild, and that it is capable of committing considerable injury to both cultivated cowpea and beans. In September, 1903, we received pods of cowpea affected by this species, which permitted sufficient study to furnish a fairly good knowledge of all stages except the egg, and an approximate understanding of the insect's life history.

DESCRIPTIVE.

The adult *Chalcodermus æneus* is one of the true weevils of the family Curculionidæ, of shape similar to the well-known plum curculio, to which, indeed, it is not distantly related. The general color is black, with more or less pronounced bronzy tinge. The elytra are coarsely and strongly punctate, as is also the thorax, which is suddenly narrowed anteriorly. It measures about one-fourth of an inch in length and is quite robust. (See fig. 13, *a*.) From a closely related species which probably has similar habits (*C. collaris*) it differs in the thoracic ornamentation, the latter (illustrated in fig. 16) having the thorax deeply, longitudinally, and somewhat irregularly strigose, while the body, particularly the elytra, is paler, with a distinct brownish and more bronzy hue.

June 3, 1901, Mr. H. P. Gould, sent from College Park, Md., numbers of the latter weevil, with report that they had been received from Mr. L. C. Reid, Rhodesdale, Md., where they were very destructive to watermelon vines. They attacked them usually in the bud and gathered in little clusters or knots, the plants soon withering and dying.

FIG. 14.—*Chalcodermus æneus*: lateral view, much enlarged (original).

The egg of *æneus* has not been described. The larva presents few characters for specific description. Its general appearance is shown at *b* (fig. 13), *c* representing the head, greatly enlarged. The pupa (*d*) shows much resemblance to the pupa of the plum curculio. Both larva and pupa are milky white in color, and the surface of each is sparsely hairy.

DISTRIBUTION.

Horn records this species from Georgia and Florida; Boheman from Mexico. In the national collection we have specimens from Grant, Fort Drum, Kissimmee, Bartow, and Key Largo, Fla.; Frierson and New Orleans, La.; Atlanta and Morgan, Ga.; Victoria and Harvester, Tex., and South McAlester, Ind. T. To this we must add reported occurrences at Dawson, Ga.; Denson Spring, Crockett, Palestine, Mount Pleasant, Augusta, and Groesbeck, Tex.; Morgan, Ga.; Cocoanut Grove, Fla., and Wedgefield, S. C.

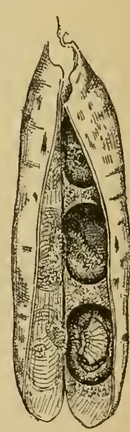


FIG. 15.—*Chalcodermus æneus*: work of larva (original).

RECENT REPORTS OF INJURY.

July 25, 1901, Mr. R. T. Smith, Grant, Fla., wrote that this species was found piercing the pods of string beans.

During May, 1902, Mr. W. M. Scott wrote of its occurence on cotton at Dawson, Ga. Complaints of injury were received also from other sources, with indication that the insect occurred in considerable numbers where reported. One correspondent said that "the weevil seems to confine itself to the stalk of the plant and stem of the leaves, inserting its beak and sucking the plant to death," while another reported that it damaged the leaves and buds, finally killing the plant.

Our first report of injury, in 1903, was from Prof. H. A. Morgan, Baton Rouge, La., to whom the beetles had been reported as troublesome to cotton by boring into the buds, leaf, stalks, and stems, this occurrence being noted near the Texas line. Later Prof. E. D. Sanderson wrote of similar injuries in Texas, and furnished data in regard to the sources from which reports of injury had emanated. These were from Denson Spring, Crockett, Palestine, Mount Pleasant, Augusta, and Groesbeck, and began with May 29 and ended June 12. Injury, however, could not be confirmed.

At Morgan, Ga., the beetles were also found on cotton and were mistaken for the cotton boll weevil. At Frierson, La., the beetles were also reported on cotton in two fields, July 7. In both cases the cotton fields where the insects were found were planted after cowpea, and in both instances the planters had observed considerable loss in cowpea the previous year, with little doubt due to these insects, although they were not detected as the cause of the loss. Dr. A. W. Morrill, of this office, who visited the infested locality, made some observations on the insect in confinement, which coincide with those reported by the first correspondent quoted in Georgia. The beetles fed on the stalks and petioles or leaf-stems and larger veins of the leaves of cotton, even when cowpeas were available, and their attacks caused wilting and dying of the leaves. When many punctures were made in the petiole just below a leaf the leaves were sometimes completely severed. In no case, however, did they attack either bolls or squares.

FIG. 16.—*Chalcodermus collaris*: adult (original).

EARLIER BIOLOGIC DIVISIONAL RECORDS.

The Division of Entomology has received reports of occurrences of this species in earlier years as follows:

September 27, 1887, from Mr. E. A. Schwarz, Cocoanut Grove, Fla., larvæ and pupæ in pods of cowpea. April 9, 1888, complaint of injury to string beans from Dr. Charles S. Herron, Bartow, Fla., who stated that the gardeners in Polk County were sustaining a heavy loss because of their crops of string beans being "stung" by this insect, the spot where the pods were attacked becoming black and rendering the beans unfit for shipment. When alarmed, the insects, after the manner of the weevils of this group, dropped to the ground and were difficult to capture. August 19 and 24, 1894, Mr. Schwarz wrote of the occurrence of this species at New Orleans, La., where it was ovipositing in cowpea. September 18, 1899, Messrs. James H. Aycock & Sons, Wedgefield, S. C., sent the beetles from cotton, mistaking them for the Mexican cotton boll weevil. It is possible that the former species might have entered the cotton bolls for hibernation, but the damage was not due to them, but evidently to a disease. It was noted by our correspondent that they were found in cotton fields which had "peas" planted along the sides.

BIOLOGIC NOTES.

September 28, 1903, Mr. A. Fredholm, Fort Drum, Fla., sent pods of cowpea affected by the larva of this species, as was positively proved by rearing. At this time most of the larvæ were mature. In a second sending of pods, however, made considerably later, the insect was still in the larval stage. The first pupa was found October 18, transformed inside of a seed, and, as all other pupæ that were noticed were in the seed, it is presumable that in most cases the larva transforms within a pod; but if the pod be rotten and lying on the ground, the pupa can easily roll away and transform to adult in any convenient spot on the earth.

The greatest difficulty was experienced in rearing the larvæ in the unnatural conditions of the office laboratory, first because we did not know the natural conditions under which the insect lived or its habits, and second because the weather was entirely unsuitable to it. If the larvæ were permitted to remain in the molding pods they died of mold, and if they were taken from the pods they failed to develop. One was found that had transformed to pupa in a pod which was rapidly decaying, and, by placing it in earth slightly moistened, it was finally reared. These notes are only given as an example of what one may expect in rearing in colder regions, under unnatural environments, species that are obviously subtropical. The larva in question transformed to pupa October 18, and to adult November 13. In this instance the pupal period was twenty-six days, which is undoubtedly from two to four times as long as normal.

NATURAL ENEMIES.

It was noticed about the middle of October, 1903, although cowpea pods were kept in a room which is ordinarily dry, that all affected by this insect were gradually becoming blackened, and a few days later assumed an advanced stage of decomposition, this being the case even when only a single larva inhabited merely the end of a pod. The molds completely covered most of the pods and was referred to Mr. A. F. Woods, Plant Physiologist and Pathologist in this Department, who stated that among them was a species of Phoma, which was either parasitic or on the border line of parasitism, and in wet seasons, at least such as the one just past, did some injury to peas. It had not, however, to his knowledge proved a very serious trouble. He also wrote, in response to inquiry, that the presence of the larvæ in one end of the pods had caused the tissue there to die prematurely and permitted the entrance of moisture, which naturally checked the further development of the seeds, thus corroborating the writer's views on this subject.

Two species of hymenopterous parasites have been reared from this Chalcodermus *Ennyomma clistoides* Town., and *Sigalphus* sp. (See Insect Life, Vol. VII, p. 280.)

The holes left in the pods affected by this weevil, which form by cracking or otherwise, leads also to secondary infestation by other insects, including scavengers. Among these, reared during the past year from cowpea, was Glover's grain moth (*Batrachedra rileyi* Wals.), which has elsewhere been mentioned somewhat more in detail (Bul. 8, n. s., pp. 32, 33) as attacking corn and cotton bolls injured by insects.

REMEDIES.

From what has been learned of the habits of the cowpea-pod weevil it does not seem that it demands remedial treatment in cotton fields. In fields of cowpea it would be difficult, although possible, to kill the insects with an arsenical spray. This would necessarily have to be applied by underspraying in order to reach the insects, and it is extremely doubtful if this would be profitable. It should be ascertained when the insect normally develops in greatest numbers in the fall, and this may lead to a partial solution of the problem. If it be found in any stage in cowpea when the pods are picked for seed, and any other species of seed weevil like *Bruchus chinensis* or *B. quadrimaculatus* are also present, fumigation with bisulphid of carbon is indicated. If otherwise, the plants, if badly injured, should be promptly and deeply plowed under. As to infestation of beans, injury may be obviated by not planting this crop in the immediate neighborhood of cowpea which has been infested the previous year. It is unnecessary to state that it would not be wisdom to spray affected beans just before picking, but within a week or two of this time it could be done if the beans were afterwards washed or a storm ensued, without any danger what ever to the consumer. In case a spray is used, arsenate of lead combined with Bordeaux mixture is advised, according to directions furnished in Farmers' Bulletin 127 (1903 ed., pp. 11–13).

ADDITIONAL OBSERVATIONS ON THE TOBACCO STALK WEEVIL.

The trouble experienced through the ravages of the tobacco stalk weevil (*Trichobaris mucorea* Lec.), at the experiment station of the Bureau of Soils located at Willis, Tex., and in charge of Mr. Lawson H. Shelfer during 1902, as reported by Mr. Chittenden in Bulletin 38 (pp. 66-70), was such as to raise grave doubts as to the possibility of the soils station being able to continue their tobacco experiments during the following year. Accordingly by request of Prof. Milton Whitney, Chief of the Bureau of Soils, Mr. G. H. Harris, of this Division, was detailed to Willis to make observations on this insect during January and February, after which another field agent, Mr. J. C. Bridwell, was appointed for the purpose and detailed by the Bureau of Soils, under the direction of the Entomologist. The work, therefore, continued from January until September, when Mr. Bridwell finished his report, which follows. It should be added that, according to Mr. Bridwell's observations, the acreage under cultivation to tobacco was not entirely sufficient for the thorough study of the life history of the stalk weevil and that the insects were not present in such abundance as to make it possible to make perfectly satisfactory tests with insecticides. Nevertheless, it is to be regretted that an under-spray of an arsenical solution was not made on insects isolated on leaves for the purpose, that we might learn whether the beetles would devour a sufficiency of the poisoned leaves to destroy them. It seems probable that arsenate of lead might be so used, in spite of the woolly texture of the under surface of tobacco; at least we suggest, if a good opportunity should offer, that it be tried. From the observations of Messrs. Shelfer, Harris, and Bridwell there can be no doubt that this is one of many species of insects which are what we term periodical, or, in other words, irregular as regards injuriousness; and it may be some time before injury is reported similar to that which happened in 1902, while again the insect might appear in great numbers a year or two hence. Some additional facts were learned in regard to the insect's life history, and it is to be especially noted that it feeds on potato, which has suggested the use of potato and jimson weed as trap crops.

WASHINGTON, D. C., *September 5, 1903.*

SIR: I have the honor to submit the following report upon the tobacco stalk weevil (*Trichobaris mucorea* Lec.), based upon work done at Willis, Tex., by Mr. G. H. Harris in January and February, and by myself from March until July, of the present year. The principal work undertaken was field observations of the habits of the weevil, and endeavor was made to determine its life history and particularly the place and manner of hibernation, its food plants, and if possible its original food plant, and whether the species is single or double brooded.

The remedies suggested by the habits of Trichobaris were studied, though the acreage of the tobacco and the degree of its infestation by this species at Willis were too small to make satisfactory experiments in some lines. This was particularly true of the poisoning experiments contemplated. The principal remedies studied were the use of trap rows and the destruction of the tobacco stalks and stubs. The results obtained may be stated briefly as follows:

Among cultivated crops *Trichobaris mucorea* attacks both the Irish potato and tobacco. It feeds upon horse nettle (*Solanum carolinense*), but its particular and almost exclusive wild food plants are the two jimson weeds (*Datura stramonium* and *D. tatula*), the latter quite common at Willis. Since both Daturas are introduced weeds, it is evident that the weevil fed originally upon some other plant. There is a native Datura (*D. meteloides*) in the Southwest, and, as Mr. Schwarz has taken *Trichobaris mucorea* from it in Texas and Mr. Coquillett also in California, this is without doubt its original food plant, and its occurrence at Willis indicates an extension of its range following the introduction of the other species of Datura.

The mature weevil, as a rule, hibernates in the stalks of tobacco or jimson, emerging in the spring when the weather is warm enough for the growth of the somewhat tender Solanaceæ. This year, which in Texas was nearly a month behind the usual season, the weevils were found feeding in the field in the middle of April. After a feeding period of a few days they copulate and oviposition begins. In the jimsons the egg is laid in the forks of the branches, but in tobacco at the lower side of a midrib of a leaf where it joins the stem. The larva may succeed in penetrating at once to the pith, and in tobacco bores out the pith from the root to the tip of the stem, producing a stunted "cabbage" plant in which the stem stops growing and all the leaves are produced in a kind of head on the short stem. The more usual course, however, is for the larva to wander about for a time just under the bark. It is not unusual for it to complete its transformations without penetrating to the pith at all. The course of the larval tunnel is usually irregularly spiral and the whorls are frequently so near together as to produce a girdling of the stalk, an effect known to the planters as "ring worm." This girdling may not particularly injure the plant, but frequently the plant is so deeply cut and so weakened that it is likely to be snapped off by strong winds. Ordinarily the insect's transformations are completed in the pith. When this is the case the fully grown larva cuts a cylindrical hole through the wood to the bark and uses the woody particles thus obtained to construct its pupa case. The life cycle was not observed, but it was estimated that this period did not exceed 75 days. Apparently there is only one brood in a season, the weevil maturing in June or July and in some cases probably later, remaining in the tobacco or jimson stalk if undisturbed until the next March or April.

Two other species of Trichobaris were found at Willis and their habits observed. These are *T. texana* Lec., boring in the larval condition in the stems of bull nettle (*Solanum rostratum*), and *T. compacta* Casey, breeding in the seed pods of the jimsons. These species may readily be mistaken for *T. mucorea* by one not familiar with insects.

It is hardly feasible to poison the weevils upon tobacco by means of a spray, since they feed almost exclusively upon the under sides of the midribs in a position almost impossible to reach by spraying. They might be reached by dipping the plants in a solution of lead arsenate when they are planted out. Poisoning on trap rows of jimson or potatoes by means of a spray would be effective if done thoroughly, for on these plants the weevils ordinarily feast upon the upper side of the leaves.

Ordinarily there will be but little use of trap crops, but undoubtedly considerable benefit would be derived by planting a trap crop of jimson or Irish potatoes in cases where the proper care has not been exercised in destroying the weevils. Perhaps the potatoes would be preferable, and they should be planted very early and then thoroughly sprayed a few days before the tobacco is planted out.

The main reliance in all cases should be the burning of all stalks and stubs of tobacco and jimson. The sooner this is done after the tobacco is cut or pruned the better, for some of the weevils will emerge from the split and broken stalks and hibernate elsewhere. Even if this is not done until the latter part of the winter almost all ot the weevils will be destroyed. This method, if continued in a given region from year to year will almost eliminate the injury of the weevil in that region.

Respectfully submitted.

J. C. Bridwell.

Dr. L. O. Howard,
Division of Entomology, Washington, D. C.

REPORT OF INVESTIGATIONS AND EXPERIMENTS ON FULLER'S ROSE BEETLE IN SOUTHERN CALIFORNIA.

By Fdk. Maskew, *Horticultural Inspector.*

The insect found infesting and destroying the strawberry fields at Tropico, and the strawberry, raspberry, and Loganberry vines at Burnett, Los Angeles County, has been identified (from specimens sent) in the Division of Entomology of the Department of Agriculture as Fuller's rose beetle, *Aramigus fulleri*. A very complete account of the biology of this insect and a comprehensive list of its food plants may be found in Bulletin No. 27, new series, of that Division. The economic points contained there may be summed up as follows: The insect is wingless, probably one-brooded; the eggs in batches of from 10 to 60 are secreted by placing them between the loose bark and the stem of the plant just above the surface of the ground, and the principal injury to the plant attacked, in case of the strawberry, is accomplished during the larval period.

The writer's attention was called to the condition of strawberry fields in Burnett, May 19. At that time the vines were commencing to wilt badly, and upon lifting some of them they were found infested with a grub. This case was promptly reported, specimens sent for identification and a complete inspection of all the strawberry plants in Burnett commenced. Associated with me in this investigation was Horticultural Commissioner Strong, and it is due to the exercise of his practical judgment on many occasions that several of the most important facts in the case have been cleared up. The number of strawberry plants in this immediate vicinity may be safely placed above the 2,000,000 mark. These were inspected, row by row, and all the dead and wilted plants lifted and examined. This survey showed the strawberry fields and vines with few exceptions to be in a good, thrifty condition, and also showed that the insect in question was confined at this time to two well-defined spots. Outside of the infested areas the death of the plants had been induced by several causes; in rare instances the cause could be traced to wireworms and also cutworms, and occasionally a colony of ants had killed the plant by loosening and removing the soil from around the roots; but by far the greatest number, fully 90 per cent, had succumbed to causes other than insect depredations. One grower assured the writer that the cause was exhausted vitality, the plant having blossomed itself to death. Another attributed the cause to the presence of alkali salts in the irrigating water, while a third was confident that in his case it was the result of commercial fertilizer. In the opinion of the writer, based upon the observation of thousands of plants, the prime cause of death to the young plants was careless setting.

The principal varieties grown in this district are the Brandywine, the Lady Thompson, and the Arizona. The Brandywine is the only variety found to be attacked by the grub up to the time of writing.

The method of attack upon the plants, as observed this season, is as follows: In the latter part of April or early in May the grubs enter the plants by boring into the stem 1 or 2 inches below the surface of the ground and tunnel upward to the crown. Here the work continues till the plant is killed. No evidence was found of any boring into the stems of the plant above the crown, nor any destructive work upon the foliage. Upon the death and eventual drying up of the plant the grub apparently returns to the soil, being found in great numbers in the soil immediately surrounding the roots of the dead plants. In very few instances were grubs found in plants that had become dried up, and in no single instance was a pupa ever found in the plants. The depths to which the grubs penetrated the soil appeared to be governed to a great extent by the moisture. In parts of the field where the plants had all been killed and the soil allowed to become dry, the majority were found at a depth of about 5 inches. Where irrigation had been continued and the soil was moist they were found within 2 inches of the surface.

The first pupa was found June 3, and the first beetle June 17. July 28 beetles were numerous upon and under the litter on the ground, and the soil surrounding the roots of the plants contained numerous specimens of larvæ, pupæ, and beetles.

Experiments were made, at the request and with the assistance of the owner of the infested patches, with carbon bisulphid. The object sought was to learn whether the soil could be practically cleared of the grubs, and the question of injury to plant life was not taken into consideration. The ground was irrigated, and then allowed to dry off until the moisture conditions were judged such as would conduce to the most effective diffusion of the vapor. One-third of an ounce was used as a dose, and injections were made as follows: One injection every lineal 3 feet in the row, one every 18 inches, and one every 2 feet. In this instance the majority of the grubs and pupæ were found at a depth of 5 inches, and an effort was made to place the dose approximately near this depth.

Twenty-four hours afterwards an inspection of the treated rows was made, and the following methods were employed to determine the results obtained. Four feet was measured and staked off in each row treated, the soil was removed from a width of 24 inches and to a depth of 8 inches, and carefully sifted; all insects were removed, and placed in a broad, shallow box, and allowed to remain in the sunlight 15 minutes before being counted. The count resulted as follows:

Results of experiments with carbon bisulphid in destroying grubs and pupæ of Fuller's rose beetle.

	Grubs.			Pupæ.	
	Total.	Dead.	Alive.	Total.	Dead.
One-third ounce to 3 feet	55	43	13	1	1
One-third ounce to 2 feet	42	35	7	0	0
One-third ounce to 1½ feet	36	34	2	2	2

Several forms of insects were found, including young sand crickets and wireworms in different stages, and these in every instance were dead. A second investigation later on failed to show any sign of insect life in the row that had received a dose of one-third of an ounce every lineal 18 inches. The cost of treating at this distance, which was apparently complete in its effects, would be approximately 10 cents for 75 feet of row.

This is probably the first reported instance of this insect attacking the roots of berry plants. However, the writer is of the opinion from evidence gathered that it has been working unrecognized upon the roots of strawberry in different parts of this county for some time. Fortunately, the natural spread of the pest in berry fields will be slow, owing to its inability to fly, and every effort should be made to take advantage of this condition, and to prevent its distribution by other agencies, by discouraging and preventing, where possible, the sale or removal of young plants from infested areas. It will prove practically impossible to detect with certainty (such as is required on other forms of nursery stock) whether or not eggs are present upon the berry plants offered for sale in wholesale quantities. Our past experience with this insect upon citrus trees teaches us that in its adult form it is very difficult to kill, even with our most complete and powerful methods.

This investigation has developed no practical method of combating the beetle upon berry plants, but has suggested several methods of relief and control against the larval and pupal stages.

The first practical measure of relief that suggested itself for strawberry growers with a badly infested field or old plants is to take new land. In case this method is adopted, the infested field should be promptly plowed not later than June, and summer fallowed, this to be followed by a crop of grain and summer fallowed the second season.

In the case of strawberry growers who are not in position to obtain new land, who have brought their land up to a state of high fertility, and, having at a great expense perfected their irrigation facilities, desire to continue growing berry plants upon the same ground, the carbon-bisulphid treatment if thoroughly employed will afford practical relief. This will probably have to be modified to suit conditions, and to be effective it should be used *before* the insects change to the beetle form.

In the fields of young plants the destructive work of the insect can be controlled by careful watching during the latter part of April and the month of May. All young plants which have been found infested contained but one grub. These were very small, of a bluish color, and apparently but a few days old. A careful search of the soil surrounding them failed to show any other grubs. If these plants were carefully lifted as soon as they commenced to wilt, the cause would be invariably brought up with them; and if the insects be promptly killed, the work of destruction would be very materially curtailed. A simple method that would make this work complete suggested itself to the writer during the investigation. By pushing an iron wheelbarrow containing a bed of hot coals before him, a man could effectually destroy the wilted plants taken from say two rows on either side. This would be a quicker method than searching for the grub, safer than hauling away the plants, and would be effective against any eggs remaining unhatched upon the plants.

There is no practical method known to me of saving the plant that has become infested with the larva of this insect. Carbon bisulphid stands out prominently as a remedial agent for this and other subterranean forms of insect life, and is worthy of better and more extended acquaintance on our part with its practical merits along this line.

No evidence of the presence of the strawberry weevil, *Anthonomus signatus*, nor the larvæ of an insect that works in the crown of the strawberry and was formerly supposed to be identical with *Anarsia lineatella*, the peach worm of this State, was found in any of the strawberry fields covered by this investigation.

ADDITIONAL NOTES.

Writing in response to inquiry as to the value of water in the treatment of soil infested by the larvæ of Fuller's rose beetle about the roots of strawberry, Mr. Maskew stated that although water might be of service as a remedy, it could not be used in the vicinity of Longbeach, Cal., but his experiments tended to prove that elsewhere it might be successful. "It might be possible to drown them out, but the soil in this locality is a loose, open gravelly loam, and takes water like a sponge. Water is costly in this region, and this method might cost as much or more than carbon bisulphid." It was customary to irrigate the strawberry fields about every ten days during the bearing season. In the moist or wet ground larvæ and beetles were all within

1 or 2 inches of the surface. On the dry ground they were 5 or 6 inches below the surface. He noticed no difference in the numbers of larvæ and pupæ under the above conditions, but never found a beetle in the wet ground, except once in a while one on the lower leaves of a plant. In the dry ground he found the beetles by hundreds July 28, 1903.

He observed that water had a bad effect on the insects in their younger stages, which corresponded with our office experiments. He filled an 8-inch flowerpot with soil taken from an infested field, and in it placed 20 pupæ and 10 larvæ, covering with a piece of lawn and placing the pot in a tin pie-plate. He applied water as for a growing plant, with the result that only one beetle was obtained by this experiment.

As the first sending of larvæ received by the writer, who had charge of them, failed to transform in moist earth, another lot was placed in a large earthern pot and kept moderately dry, the top only being slightly moistened occasionally. From this jar nearly all the beetles issued, showing that if it should be possible to irrigate at the time when the species is undergoing transformation from the larva to the pupa, and from pupa to adult, the insect could be killed by this method alone. We have also to record the receipt of larvæ and adults of this species from Mr. Harry G. Wolfgang, Leetonia, Ohio, who wrote January 11, 1904, that it was especially destructive to citrus, hibiscus, and vinca, the last being a new food plant, while we have not received previous records of the occurrence of this species in Ohio.—F. H. C.

IMPORTATIONS OF BENEFICIAL INSECTS INTO CALIFORNIA.

By C. L. Marlatt.

In the annual reports of the Entomologist of this Department for the past four years (1900–1903) brief accounts have been given of the introduction of various foreign beneficial insects, including the South African black scale parasite, *Scutellista cyanea*, the European moth parasite of the larger scale insects, such as Lecaniums and mealybugs, *Erastria scitula*, the European plant-louse ladybird, *Coccinella septempunctata* and an Australian species, *Leis conformis*.

Of these importations the only one which has yielded a marked success is that of the South African parasite, and this insect is apparently duplicating against the black scale the wonderful work of the Vedalia against the white scale in California. In his annual report for 1900 Doctor Howard gives the history of this importation, and the earlier one into Louisiana. The subsequent annual reports cited bring the records down to the summer of 1903. In August of this year (1903) Mr. Craw, first deputy commissioner of horticulture, and quarantine officer of California, replied to a telegram of inquiry that the most sanguine expectations had been surpassed by this species. He telegraphed under date of August 28 that it is established in every county south of Concepcion, that it is very plentiful in Los Angeles and San Diego counties, and that he is still sending it out from his office in San Francisco. The Los Angeles commissioners had also by that time distributed over 400 strong colonies near Escondido, and stated that the insect was spreading naturally and rapidly from the points of distribution, and as a result there was a feeling of great confidence among orchardists.

The writer spent portions of November and December in California, and particularly investigated the status of this parasite. A visit to the office of the horticultural commissioners of Los Angeles County November 27, 1903, enabled him to note the process of breeding and shipment of colonies of the Scutellista. The secretary of the board, Mr. Jeffrey, stated that 1,000 colonies had been sent out from his office, and that probably as many more had been distributed directly from orchards.

The principal source of supply at this season was the pepper trees. Hitherto these trees have been rather maligned as harboring the black scale, and facilitating the reinfestation of adjoining citrus and olive orchards, but with the introduction of the Scutellista this tree plays a very useful rôle, because the black scale upon it seems to breed more irregularly, at least in some regions, than on the orange, and hence supplies food in the proper stage for the parasite over a much longer period than is the case with citrus trees.

The Scutellista larva feeds only on the eggs, and never has been discovered to attack the young or gravid female host insect. It is therefore desirable that the scale should be present in the egg stage at practically all seasons of the year to allow the parasite to go on breeding unchecked. There is some evidence, however, as will be shown later, that the parasite may have a resting period corresponding to the winter months, during which the great mass of the black scale is in the larval stage, thus accommodating itself to the habits of its host.

It will be apparent that the usefulness of this parasite depends on how nearly it destroys all of the eggs produced by the female Lecanium, and it is very interesting, in this connection, that the repeated examinations made by Mr. Jeffrey and others and by the writer revealed in no instance the escape of a single egg in a parasitized scale. If the eggs are few in number the parasite comes to full development, but yields a much smaller insect; on the other hand, a large, well-fed female scale will develop a parasite of unusually large size, but the larva in either case seems to continue feeding as long as there are any eggs to be devoured.

A common method of distributing the parasite is to cut branches from pepper trees and tie them to the orange trees in various places through the groves. The distributions made from the central office in Los Angeles are of bred parasites, which are sent through the mails in small wooden boxes. The abundance of this parasite on the pepper tree is something amazing. Some branches of this tree plastered with scale insects were examined, and every scale contained the parasite, either in the larval, pupal, or adult stage, and they were emerging in the breeding jars by hundreds.

Later, December 19, the writer, in company with Mr. Jeffrey, made an exploration of the region between Monrovia and Azusa, in Los Angeles County, chiefly about the latter place. Various ranches were inspected where the Scutellista had been liberated. The black scale in these ranches was practically cleaned up, and the few remaining scales were parasitized. The natural spread of this parasite from one ranch to another was well illustrated in this region, and all of the ranchers were most enthusiastic over the outlook. Nothing in the way of control by a natural enemy has given such promise or has roused so much interest in California since the introduction of the Vedalia.

The following day a trip was made, in company with Commissioner Strong and Horticultural Inspector Fdk. Maskew, through the coast region near Long Beach. Here a most interesting outcome was noted. Mr. Maskew, who has been very much interested in the distribution of this parasite, and had failed to get as large a supply from the Los Angeles office as he desired for his local distributions, accidentally discovered that the horseweed (*Erigeron canadense* L.) growing in the neighborhood of some pepper trees bordering an orchard where a colony had been placed was thickly infested with the black scale, and, to his surprise and delight, he found that the scale on this weed was extensively parasitized by the Scutellista. From this stock he was enabled to distribute quantities of the parasite throughout his district. More interesting still was his discovery that the black scale occurred quite commonly on various other weeds, such as cocklebur and ragweed, and very extensively in an adjoining field of Chilipeppers, and that on all of these plants the infestation with Scutellista was becoming very general, so that he had here an immense stock of parasites for distribution. The writer visited this locality, and confirmed by a personal examination the abundance of the scale on the plants named, and particularly on the Chilipeppers, and the general infestation of this scale with the parasite.

The evidence pointing to the partial hibernation of the parasite, already noted, was furnished by Mr. Maskew. He had made considerable collections of the scale on the horseweed for breeding and for dissemination in orchards. The weeds were at this season of the year entirely dead and dry. Some of them had been kept in jars very much exceeding the normal time for the emergence of all the parasites, but were still yielding them, indicating that there is at least a notable irregularity in the time of emergence, and a possible resting or hibernating period. In the coast districts, as represented by Long Beach, the black scale is not so distinctly single-brooded as it is in the higher regions bordering the mountains, and this was especially notable in the case of the Chilipeppers. It is evident, from what has been said that the danger of the parasites being exterminated during the winter is not very great in southern California.

The writer also investigated the conditions about Santa Barbara, where there have been some distributions of this parasite, and notably the Gillespie ranch. This ranch is remarkable for the great variety of horticultural and ornamental plant species and varieties represented in it. It is under the charge of Mr. Compton, an experienced horticulturist and gardener. The writer was assured by Mr. Compton that two years ago the olive and citrus orchards and many of the ornamental trees and shrubs were covered with the sooty fungus from the black scale which thickly infested the premises. About that time he obtained a colony of Scutellista. In April of 1903 this parasite had so multiplied that he was unable to find a scale anywhere that did not contain a larva of the Scutellista. At the time of my visit these premises were in splendid condition, perfectly clean, and as fresh looking as could be wished, and this result seemed to have been accomplished in the main by this parasite. So perfect had been the work that a living scale was not to be found anywhere. It must be said, however, that this was an off year for the black scale in this region, and that on other ranches where the Scutellista had not been introduced the black scale was doing less damage than ordinarily. For example, the Crocker-Sperry ranch, which the writer saw some seven or eight years ago blackened with *Lecanium oleæ*, was this year comparatively free from serious attack. This ranch, however, had been regularly treated with petroleum washes.

The method of hibernation, or the winter behavior of this parasite, in view of its extraordinary promise, are matters of particular interest, and the writer, therefore, under date of February 24, 1904, requested Mr. J. W. Jeffrey, the secretary of the board of horticultural commissioners of Los Angeles County, and Mr. Frederick Maskew, an inspector of the same county, already referred to in this report, to send any data which they had obtained bearing on the subject of hibernation, or the exact conditions of going through the winter in orchards, on pepper trees and other plants; and also, in the same connection, any records which they might have showing the time covered by a full generation, or the variation of this period at different seasons of the year. The information given by Messrs. Jeffrey and Maskew is appended herewith, and should be credited to the horticultural commissioners of Los Angeles County, all of the members of the commission and inspectors being more or less jointly responsible for the work done on this parasite and the information gained. As pointed out by Mr. Jeffrey, the South African parasite presents such varied phases of development in different localities and situations, under different scale conditions, that it is impossible to form accurate conclusions without a thorough study of its life history made in a systematic manner. The general status of the distributions and abundance of the parasite and winter conditions are given by Mr. Jeffrey, in letter dated March 7, as follows:

From the 15th day of last August to the 15th day of January this office has distributed about 25,000 adult flies. They were taken from a colony established upon a pepper tree at Pasadena on the 26th day of August, 1902. During this period of five months of distribution the greatest activities occurred in August and December, 32 per cent being sent out in December. You will notice that the time covered is concurrent with that of the greatest development of the scale upon the pepper trees from which we obtained our supplies. But the most active orchard work of the flies must occur in the early summer, when the scale is in the egg stage upon the citrus trees.

From the first of January to the first of March the Scutellista entered a period of greatest dormancy, in which a large portion died in the larva, pupa, and adult form. We are now breeding them again in large numbers. However, we noticed in several orchards in sunny situations the insects working all through this time of general dormancy as if it were midsummer, the orchards being in all cases young, and, consequently bearing scale in all stages of development.

From this we conclude that with the exception of a short time in the cooler weather the Scutellista has no period of inactivity, but works in all cases where the scale is in the egg stage.

Mr. Maskew's notes, received with the above, are very interesting and instructive, and are quoted substantially as received below, and are the result of instructions from the Horticultural Commission of Los Angeles County to make weekly observations on colonies liberated in his own inspection district:

October 15.—A few flies. Pupae common but not numerous. Larvæ (not identified) very abundant.

October 19.—Flies more in evidence. Pupæ very abundant. Larvæ (not identified) becoming more scarce.

October 30.—Flies very numerous; numbers of them to be seen upon the wood and foliage. Old scale showing evidence of a general exit. Pupæ under scale becoming scarce. Larvæ (not identified) in all sizes but more rare.

November.—*Scutellista cyanea* was found in all three stages during each week of this month, but upon a different class of host plant. The majority were found upon horseweed, cocklebur, pepper trees, and olive, about in the order named from a numerical standpoint. Flies bred from parasitized black scale upon belladonna and chili pepper taken during the month of November, proved to be *Tomocera californica*, *A. mytilaspidis*, and one unknown to me which had all the earmarks of a Proctotrupid.

December.—*Scutellista cyanea* was found in all three stages during each week of this month, principally upon pepper trees, weeds, and upon chili pepper.

January.—During each week of this month the parasite was found as follows: Larvæ very scarce, pupæ and flies abundant, particularly upon chili pepper. A very large number of dead flies were found under the shells of black scale, more so than during any other time of this investigation. Cause unknown to me.

February.—The larva and pupa of the insect in question were rarely found during the weekly investigations of this month. Flies were abundant upon the foliage of citrus trees and upon the stems of chili peppers during most of the bright sunny days of the past month. The mortality of adult flies under the scale continues, but not so apparently as during January.

"Length of time of a generation under natural conditions." I have but one positive record of this. On August 14, 1903, I liberated a colony of *S. cyanea* (flies) on the premises of G. A. Lindsay, Long Beach. No Scutellista had been placed previous to this nearer than 4 miles away. I was in a position to watch the progress of this colony closely. I soon saw by the color and appearance of the scale (*L. oleæ*) that they were parasitized. On October 8, 1903, I was investigating the progress of the parasites and upon removing a full-grown black scale, a fully developed Scutellista emerged from the shell into my hands. This makes fifty-five days from the time the flies were liberated and the first appearance of the adult of the next generation.

On October 18, 1903, I found a large quantity of horseweeds in a gulch to leeward of a lemon orchard in which *S. cyanea* had been placed. These were found to be covered with black scale (*L. oleæ*). Upon investigation it was found that the scale was extensively parasitized, at least 50 per cent; upon a piece of horseweed 16 inches long I removed 80 black scale; 42 of these contained parasites, the majority being *S. cyanea.*

On October 19 I cut these weeds into short lengths, placed them in fruit jars, covered the tops with lawn and distributed them in the different citrus orchards. The owners agreeing to liberate such flies as emerged once every twenty-four hours. On December 18 flies were still issuing from the weeds placed in one of these jars. Later on this jar was removed to the office in Los Angeles, and the commissioners informed me that flies (*S. cyanea*) continued to emerge up to the ninety-seventh day after being placed in the jar. These weeds were mature when placed in jar, and the scale upon them was fully developed.

The points of greatest interest shown in the notes above quoted are that at the height of the breeding season (in August and September) the life cycle of this insect is about fifty-five days, and that during the colder season of winter these insects, as already indicated in my own notes, enter a period of semihibernation which may extend over a period of three months. The bearing of these facts on the usefulness of this parasite is very apparent. The feature of greatest anxiety was how it would pass the winter season during which, in the case of many citrus groves at least, there would be no food for them. This problem seems to be solved by the hibernation of the insect, which bridges very nicely the period referred to. On the other hand, it is shown that where conditions are favorable—that is, in sunny situations and where the food supply exists due to the same conditions, activity continues throughout the winter. There seems to be no possible reason for doubting, therefore, the full establishment of this insect in southern California and its present and prospective great usefulness.

Scutellista cyanea, of which such good showing is now made, as pointed out by Doctor Howard, is probably of Oriental origin, having first been described by Motschulsky, from Ceylon, from which place it may accidentally have been carried to Italy and South Africa, in both of which localities it has become established, and is most beneficial in keeping in check the larger scale insects.

Other recent importations.—The European moth (*Erastria scitula*) does not seem to have made any very startling developments, and I could get no reports of its having given any evidence of usefulness. It will be remembered that this insect was sent to this office by Prof. Antonio Berlese, of Portici, Italy, during the year 1902, and was forwarded by Doctor Howard to Mr. Alexander Craw. It was liberated in several places, and the preliminary reports were favorable enough to show that there is a good chance of its becoming established.

Of the European ladybirds, *Coccinella septempunctata* and the Australian *Leis conformis*, I could learn nothing especially favorable. The first is an omnivorous feeder, and will eat its own larvæ or the larvæ of other ladybirds as readily as it will plant-lice, and hence its utility is open to some considerable question.

Older importations.—Of the older importations into California the Vedalia is maintaining its usefulness. It is being bred regularly by Mr. Craw and some of the county horticultural officials. Whenever notice of an outbreak of the white scale comes to headquarters some of these beetles from breeding cages are sent out, always accompanied with the request for a return sending of as large a quantity as practicable of wood infested with the scale. By this means the food supply for the rearing of beetles is kept up and it is made possible to send out new beetles promptly to all applicants. The rapidity with which a colony of scale is cleared up by these insects is something marvelous, a few weeks only being sufficient for it to clear up a considerable area of infestation.

The older principal insect enemy of the black scale in California is the imported *Rhizobius ventralis*, which has been so very effective on the Cooper ranch and in some other coast districts of California. It has never proved to be of any special value in the drier regions away from the coast. These conditions seem still to be true of this insect. Its usefulness, therefore, is comparatively limited, as much of the important orange and citrus area is beyond its range of effectiveness. *Rhizobius ventralis* also has shown itself very efficient against *Pulvinaria innumerabilis* on apple. This Pulvinaria very badly infested certain apple orchards, and was completely cleaned up in eight weeks after the introduction of this ladybird, as reported by Mr. Maskew.

Every little while others of the beneficial insects imported by Koebele turn up, even where they seem to have completely disappeared for a number of years, and it is not improbable that more of them have maintained themselves in California than has been believed, though in very limited numbers.

INSECTS INJURIOUS TO STOCK IN THE VICINITY OF THE GULF BIOLOGIC STATION.

By James S. Hine.

The Gulf Biologic Station is located at Cameron, La., near the mouth of the Calcasieu River, which empties into the Gulf of Mexico a few miles from the Texas boundary. The writer arrived there August 14, 1903, with directions from the United States Department of Agriculture to investigate the stock insects of the region. A report on a subject like the present one, observed for a short time, must necessarily be incomplete, and some suggestions are omitted which if developed might lead to important results.

Mosquitoes are very abundant and are serious pests to both man and beast. The director of the station, Prof. H. A. Morgan, is actively engaged in studying them.

Several of the Muscids, such as the stable fly, horn fly, screw-worm fly, and Hippelates flies, are also plentiful.

Although directed to investigate stock insects, the writer understood that horseflies of the family Tabanidæ were to be his special subject, consequently most of his time during a two weeks' stay was devoted to these forms.

The whole country is only a few feet above sea level and is favorable for the development of the Tabanidæ on account of the large acreage of wet and marshy land. Running nearly parallel to the shore of the Gulf is a series of alternating ridges and depressions. The depressions form extensive fresh-water marshes, over a part of which the water stands the year round. Such species as oviposit over mud or stagnant water find ideal conditions in this region, and consequently some of them are abundant.

SPECIES OF TABANIDÆ OBSERVED.

A large number of species have a range such as would safely include them within the fauna of Louisiana; and besides the writer has seen nearly a dozen species from that State, but during his stay there only five were collected or observed, but at least three of these are among the worst stock pests of the family, and taking into consideration their abundance in the region, they are certainly a serious drawback to stock raising.

Chrysops flavidus Wied. was the only one of its genus observed, and owing to the lateness of the season only now and then a specimen was seen. It is said to have been an abundant and troublesome pest earlier.

Tabanus atratus Fab. was occasionally seen. As in other localities, it is present through nearly the entire summer, but usually not abundant enough to be considered a serious pest. Only a few specimens were observed molesting horses and cattle.

Tabanus lineola Fab. is a widely distributed species and everywhere is of especial economic importance. It was common at Cameron, and is one of the three species referred to above as being especially injurious.

Tabanus costalis Wied., the common greenhead, was abundant and appeared to be more persistent in its attacks than any of the others. When sucking blood it is usually located on the under parts or on the fore legs, where an animal has most difficulty in reaching it, and once it alights it is pretty sure to satisfy its appetite before leaving.

Tabanus quinquemaculatus Wied. has not been reported from the United States heretofore, but the commonest species observed at Cameron agrees very closely with Wiedemann's description. Besides, it is reported from Mexico by both Wiedemann and Bellardi, so it would not be strange to find it in Louisiana. This species appears much like *costalis*, but is larger, has two purple bands on the eye instead of one, and the costal cell is hyaline. It is also close to *lineola* in appearance, but the color of the vestiture of the body is decidedly more yellowish, and the upper purple band of the eye is noticeably narrower than in that species. Besides, it averages larger than either *costalis* or *lineola*, but undersized specimens are often met with.

Since no systematic experiments were carried on at the Gulf Biologic Station, what the writer has to say regarding remedies may be considered as suggestions, derived partly from observations on the conditions existing in that section, and partly from work and experience in Ohio.

NATURAL ENEMIES.

The natural enemies of the Tabanidæ is an interesting subject for investigation at the Gulf Biologic Station. The writer is under obligations to Messrs. Ashmead and Coquillett for the names of most of the species mentioned below.

Monedula carolina Fab., a large and attractive species of the family Bembecidæ, is common, and its habit of flying around horses and cattle for the purpose of catching Tabanids and other stock pests is so noticeable that it has received the common name of horse-guard.[a] One commonly sees from one to three or four of these at work around a single animal.

Bembex belfragei Cr. belongs to the same family as the last and like it is an important enemy of horseflies. It has different habits, however, for instead of capturing prey around animals, it flies about the fields in the vicinity of marshes and captures males and females at their breeding grounds. It is a common occurrence to see a specimen carrying an adult Tabanid.

Both the above species deposit their eggs in burrows which they

[a] A name which it shares with the great digger wasp (*Sphecius* [*Stizus*] *speciosus* Dru.).

make in the sand, and they store the burrows with insects for the young to feed upon when they hatch. It is not uncommon to find from half a dozen to a dozen specimens of Tabanus in a single burrow, besides other insects. Professor Morgan says that he has taken seventeen horseflies, one Syrphid, one Tachinid and one Stratiomyiid from a single burrow.

Crabro 10-maculatus Say, another wasp, is an expert at catching Tabanids, and the writer often saw them capture the flies and carry them away. None of their nests was found, but it would appear that they have about the same habit in this regard as the Bembecids.

Erax maculatus Macq. and species of Deromyia were rather common and were often observed feeding upon different species of Tabanidæ.

That chickens may become a factor in destroying stock pests was proved by the fact that they were often observed following cattle in the pasture, picking off such Tabanids as alighted on the lower extremities of the animals for the purpose of sucking blood.

METHODS OF CONTROL.

In my "Tabanidæ of Ohio" I suggested the use of kerosene on the surface of the water for killing larvæ hatched from eggs deposited over water. Of course this method could not be used in cases where deposition took place over damp ground, as was observed at Cameron. One finds eggs of *costalis* and a number of other species in such places quite frequently.

With so much standing water to be considered, it would be an immense undertaking to use kerosene for killing adult flies, as suggested by Porchinski in Russia, and commented on by Doctor Howard in Bulletin No. 20 (n. s.), Division of Entomology (p. 24). It appears that both of the above suggestions, as well as others that might be mentioned, are of most value in special cases; in fact there is seldom a single remedy in use in economic treatment of insects that is appropriate at all times with reference to a particular species or group of nearly related species.

It is my belief that species of the genus Tabanus have a habit which if better understood might be utilized in trapping them in numbers sufficient to materially lessen their ravages. I refer to their habit of collecting in certain places, as on buildings, fences, and the like. The habit has been observed at different times and in different places but I saw it more forcibly at the Gulf Biologic Station than at any other place I have observed. The sexes of the last three species of Tabanus mentioned above flew around the station building in numbers, often resting on the siding and windows or striking against the glass and screens; then flew away so rapidly that the eye could not follow them. August 23, I obtained permission to open the screens from one of the doors to see what the result would be. The screens from a doorway (7 by 5½ feet) were left open from 10 in the morning to 3 in the afternoon, after which between a pint and a quart of flies of the size of the common *costalis* were procured from the windows upon the inside of the building. All but about a dozen of these were females, which, as was proved by dissection, had not yet laid their eggs. I believe that a trap might be manufactured that would attract Tabanids in the same way that they are attracted to the building to question.

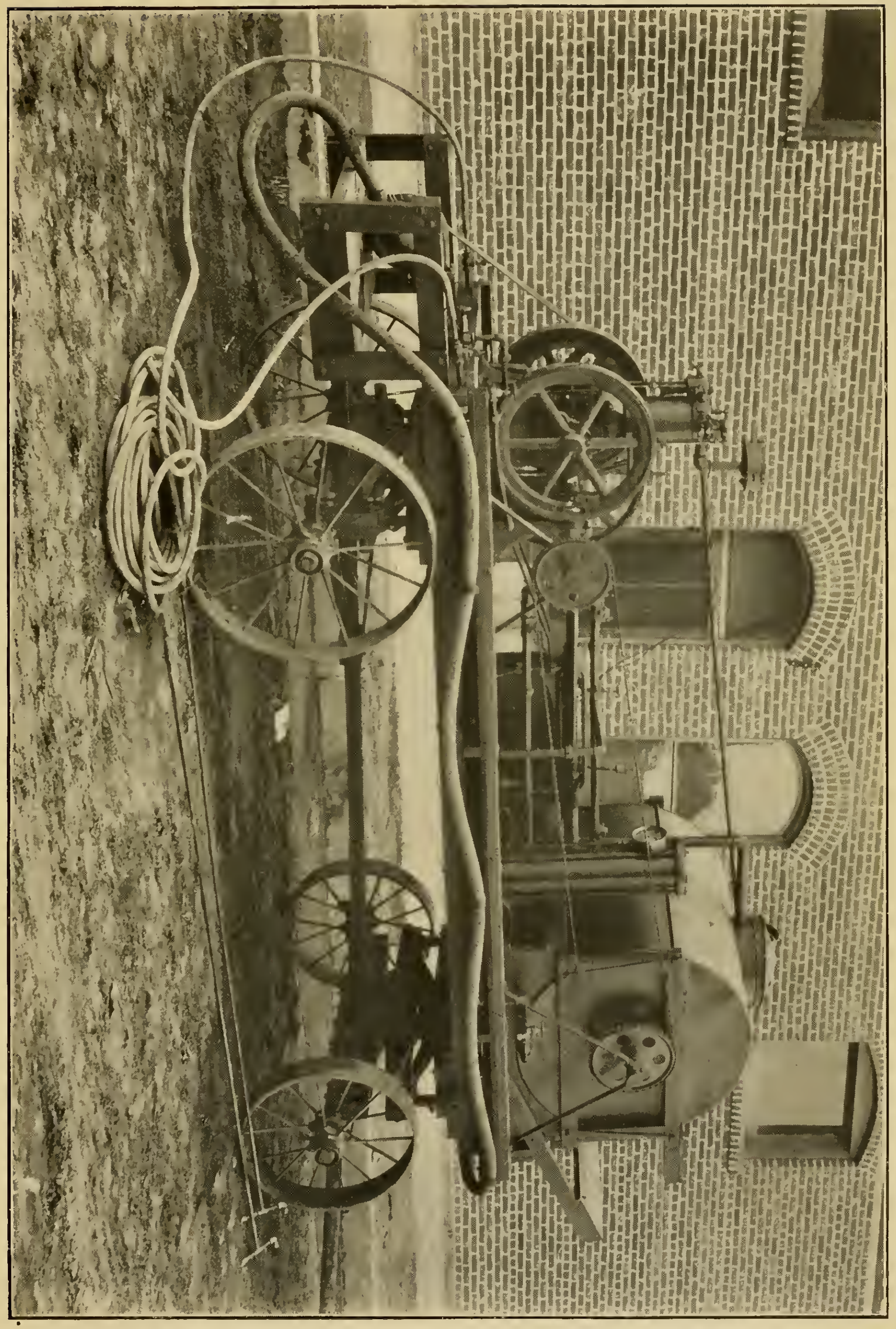
It is worth mentioning that a few females of *atratus* were taken with the above, so it is probable that if this species had been as numerous as the others just as striking results could have been obtained with regard to it.

THE NEW DISTILLATE SPRAY IN CALIFORNIA.

By C. L. Marlatt.

On account of the small margin of profit in the growth of citrus fruits fumigation is now often considered too expensive, and a good deal of spraying is done in California with oil washes. The use of distillate emulsion, prepared substantially after the formula of kerosene emulsion, described in detail in other publications of this Office, has been very generally discontinued, and in its place a mechanical mixture of the distillate and water is employed. The California oil lends itself to emulsifying with water far more readily than do the lighter oils of the East. The process consists in putting the oil and water together in the spray tank, which has a capacity of about 200 gallons. The oil being added to the proportionate amount to give the strength desired, is kept thoroughly emulsified with the water by means of a rotating agitator in the tank operated by the gasoline engine. A very homogeneous and fairly stable milky fluid is secured, which does not separate for hours, and enables the mixture to be sprayed with perfect confidence as to uniformity of strength. Two or four lines of hose are commonly employed, and a pump provided with an air chamber to equalize the pressure.

There has been considerable complaint of spotting of fruit from the use of this mixture. It is now determined, however, that a 2 per cent strength does not hurt the foliage or fruit, but, unfortunately, is not always thoroughly effective against the scale. The lemon tree will stand a stronger mixture than the orange. Mr. F. Kahles, the manager of the Crocker-Sperry ranch, near Santa Barbara, employs a 2½ per cent strength for the orange and a 3 per cent strength for the lemon. Mr. S. A. Pease, the horticultural commissioner of San Bernardino County, uses 2 per cent strength on the lemon and 3 per cent strength on the orange, without injury to leaf or fruit. Mr. Pease has also used a 5 per cent mixture against the black scale on apricot after



DISTILLATE POWER SPRAYING APPARATUS USED IN SAN BERNARDINO COUNTY, CAL.

[From photograph furnished by S. A. Pease.]

the leaves are off of the trees, and the same strength in winter on apple and cherry to kill the eggs of Bryobia.

The writer witnessed the operation of two excellent power-spraying machines of the character above indicated, built under the direction of Mr. S. A. Pease, for use in San Bernardino County. The work in hand was the spraying of some orange orchards of large trees for the yellow scale (*Aspidiotus citrinus* Coq.), and the apparatus worked remarkably well, and the results seem to be most satisfactory. In all, nearly 300 acres of orchards have been successfully treated by Mr. Pease. The following description of this apparatus (see Pl. I), of which the county of San Bernardino keeps three in operation, is supplied by Mr. Pease:

The San Bernardino County power spray machine, built by Osler & Miner, Pomona, Cal., is designed to use either distillate spray or other mixture, and is equipped with a 2-horsepower Root & Van Dervoort engine, and a double-acting pump with 2-inch cylinders on each end, 10 inches long. The piston of the pump is driven backward and forward by use of bent shaft, with which a large cut gear is placed on the end, run by a pinion on engine shaft.

The suction of the pump is taken from the bottom of the agitator tank and discharged into the air tank, which will withstand 300 pounds pressure. The power of the engine is sufficient to run up pressure of 300 pounds or more, and to run four lines of spray hose with two nozzles on each line, which will consume about 250 gallons of spray mixture in thirty minutes. The agitator tank is horizontal, holding 255 gallons, and has a shaft directly through center in which three sets of paddles are bolted, each being 4 inches in width. The paddles are placed on shaft at different places, and point in different directions. As the paddles revolve they throw the mixture in one direction. There are three lines of breakers placed on the inside of the tank lengthwise, which throw the fluid back, making a double mixture. These paddles are operated by means of two sprocket wheels, one placed on end of the bent shaft at engine, and the other on the paddle shafting at the end of the tank, connected by chain.

There is a small horizontal centrifugal pump run by belt from the engine, which is used together with 25 feet of suction hose to pump water out of ditch or standpipe. By this means the agitator tank is filled in four or five minutes. The above apparatus is mounted on a platform over a set of iron trucks with 5-inch tires. A pair of bolster springs are used which will carry a weight of 8,500 pounds.

The methods of supervision of treatment of orchards in California are always instructive. In Los Angeles County there is direct supervision of the work by the horticultural commissioners. The fumigation or spraying is done by contractors, but with the provision that the work must be approved by the proper county official before payment can be collected. At Riverside the work of this sort is done by the county directly, and a charge is made for actual cost, plus 10 per cent. A similar method is followed in San Bernardino County.

THREE BRITISH FRUIT-TREE PESTS LIABLE TO BE INTRODUCED WITH IMPORTED NURSERY STOCK.

By Frederick V. Theobald, *Wyecourt, England.*

The subject of the importation of injurious insects from one country to another is a most important one. That many European pests have been imported into America and into the British colonies is well known. These unwelcome visitors, finding their new surroundings abnormally congenial and their natural enemies absent, often cause far more harm than they do at home. It is unnecessary to mention examples so well known to all interested in economic entomology. The study of the insect pests of other countries than our own is thus rendered very necessary, so that we may be prepared to fight and prevent the new arrivals. This distribution of noxious creatures is most important in regard to fruit and ornamental plants. The notes on three British fruit pests which may easily be introduced into America may therefore not be unwelcome to the members of this Association. The three pests that appear to me to be especially guarded against and which I believe do not occur in the orchards and gardens of America are the following: The pith moth (*Laverna atra*); the apple sucker (*Pyslla mali*); the currant-bud mite (*Eriophyes ribis*).

All these pests occur permanently on trees or bushes in one or more of their stages, the winter in all cases being passed upon the plant, the pith moth in the larval stage, the psylla in the egg condition, and the currant bud mite in all stages. They can therefore be easily transported on nursery stock.

It may be said that the fumigation of the young plants or cuttings with hydrocyanic-acid gas will prevent their introduction, but from experiments I have made I am confident that the ova of the psylla and the bud mites are not in the least harmed by the treatment, and I doubt if the effect of this gas would kill the larvæ of the pith moth in question.

The apple sucker and the big-bud mite of the black currant are both such serious pests that great caution should be exercised in importing stock from England and Europe. For the latter pest we have absolutely no remedy, and the former is most difficult to fight.

THE PITH MOTH.

(*Laverna atra* Haw.)

Syn.: *L. putripennella* Zell.

This small Tineid moth has long been known in Europe by entomologists, but it was not recognized as a pest in Great Britain previous to a short note made by Miss Ormerod in 1890; a few subsequent notes were added by her, but nothing of any special value or originality.

Previous valuable observations had been made, however, by Muhlig, of Frankfort on the Main (*vide* Kaltenbach's Die Pflanzenfeinde aus der Klasse der Insekten, p. 781). During the past three years this insect has been very destructive in parts of England, notably in Sussex and Kent; observations have also been made in Gloucestershire and Middlesex, and I have seen it working among the fruit trees in Cambridgeshire in 1889 and in Huntingdonshire on more than one occasion. Since the attention of the fruit growers has been called to this pest it has been noticed quite frequently. The damage done by the larva is very great, and as there is no known remedy, it is very important to try and prevent its importation and to destroy it by drastic measures when it makes its appearance in an orchard. Miss Ormerod states[a] that "the attack appears to be very seldom noticed with us in connection with apple injury." This is not the case; it has been frequently noticed by growers, but the observations have not been recorded by them.

This pest can easily be detected by its workings and the symptoms it produces; the red larvæ, by tunneling into the buds and shoots (of all classes), cause the former to die off soon after opening and the shoots to at first flag, then wither up and eventually turn brown and die. In the first series of observations I made on this pest I found the terminal shoots only affected,[b] but, as pointed out to me by Mr. Bear, of Hailsham, all shoots and buds suffer indiscriminately, and this has been frequently observed during the past year. The dying off of the young shoots has frequently been attributed by growers to canker (*Nectria ditissima*), which I have seen to produce very similar symptoms. But by breaking open the bud or dead shoot, the true cause is soon seen by the presence of the small, red caterpillar or its brown pupa near the apex of the bud or shoot. So far I have found this insect only on dwarf trees, and reports sent me are all to the same effect. Twelve-year-old trees are the oldest I have at present detected these pests on. The fact that it is mainly on young stock has given rise to the idea in England that it has been imported. This is not so, for it not only occurs on the apple but is mentioned by Stainton[c] as being "not scarce in June on white thorn." Herr Muhlig also says that "the caterpillars live in the same way on the allied white thorn, which they more especially infest in this neighborhood (Aix la Chapelle)." Stainton seemed to doubt that the same species occurs on the whitethorn and the apple, for he says: "The dark variety appears exclusively attached to the apple; it is possible it may be a distinct species." I have found during the past year that those bred from the apple vary from the dark form mentioned by Stainton to the typical

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[a] Handbook of Orchard and Bush-Fruit Insects, p. 278. 1898.

[b] First Report on Economic Zoology, p. 68, 1903.

[c] Lepidoptera Tineina, pp. 239 and 240.

shades seen in the whitethorn living specimens, and I am convinced that they are the same.

LIFE HISTORY.

The moth is slightly less than half an inch in wing expanse. The color is subject to much variation; the front wings are often almost entirely black, the posterior wings gray with gray fringes; other specimens have the front wings mottled with dark brown, brown, and rusty brown, and the inner margin of the fore wings is white to beyond the middle, where an irregular oblique white bar proceeds to the tip of the wing, and from this two branches may intersect the black apical portion; the head is almost entirely white. The white markings are particularly variable. This insect occurs in June, according to Stainton,[a] but all those I have bred out appeared between the 12th of July and the 10th of August. The moths are very active, running with great energy, and frequently fall on their dorsal surface. They rest during the day on the twigs and stems and are then scarcely noticeable, owing to their color being similar to the rind. The egg stage has not been observed on the apple trees, but they are apparently laid soon after the moths have hatched out. I have found small larvæ on the leaves in September which I am sure were those of this moth; they reached one-twentieth of an inch in length. The next stage occurs under the bark of a twig, beneath which the small larvæ have eaten their way; others bore into the base of the buds and there they remain all the winter. The hole of entry is so small it can only be detected by microscopic examination. During January and February the young larvæ were found tunneling into the pith of the shoots and also feeding at the base of the buds. In May their work in the pith is most pronounced, and later they work into the flower stalk and eventually the whole shoot, perhaps for 3 or 4 inches, dies away. I have found them in the stalk of fruitlets and many in the buds which never develop to maturity. The larvæ live until June; the majority pupate by the 20th, but some not until the last week of the month. The caterpillar is dull reddish brown with a deep-brown head and first segment; the other segments show more or less traces of pale-brown spots, four in a row on the second and third segments and four placed in a quadrangle on the remaining segments; the two anterior segments have two lateral spots and the others one each; the apex is brown and the sucker feet rather paler. When matured they reach one-third of an inch and pupate near the apex of the shoot or bud. The pupa is bright-ochraceous brown with the head, front of thorax, and tip of the body mahogany red. On the ventral surface of the penultimate segment are two blunt processes, separate and widely diverging with hairy apices; the eyes are black and the wing cases

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[a] Manual of Butterflies and Moths, II, p. 399.

and leg cases long and pointed. The pupal stage I found varied between two and three weeks. Prior to the moth hatching the pupa frequently is forced half out of the dead bud or shoot.

According to Stainton, the larvæ also occur in hawthorn berries in September; the black variety only in apple shoots in February and March. Recent observations, however, show that all variations in color breed from the apple, and probably the larvæ in hawthorn berries are of another species, for on the haw or white thorn *Laverna atra* works just as it does in the apple.

Fortunately this insect attacks only small trees, and so can easily be destroyed by hand picking the dead buds and shoots before the moths escape. Where this has been done the pest has been kept under, and in some cases practically stamped out.

Probably autumnal spraying with arsenites would kill the young larvæ before or when they burrow into the rind of the shoots.

THE APPLE SUCKER.

(*Psylla mali* Schm.)

This apple pest causes great loss to fruit growers in this country, and has apparently increased very considerably during the past few years. It very much resembles your pear-tree psylla (*Psylla pyricola*), so ably dealt with by Slingerland.[a] This latter pest I have never detected doing any damage in England. The apple psylla which was recorded as a pest as long ago as 1837[b] has since been mentioned by the late Miss Ormerod in her reports, etc., in which the observations of fruit growers have been recorded, though but little fresh matter was added to Kollar's original paper. This pest having become more serious during recent years, I have devoted two seasons to its study, which have brought to light many new facts in its economy. As it appears to me to be a very likely insect to be imported into America on nursery stock from Europe, I include this species with a hope that the notes may help my fellow-workers should it unfortunately make its way into America.

The effect of this pest on the apple trees is very varied. The larvæ and pupa suck the juices of the buds and frequently check their growth entirely, the buds turning brown and dying; at other times they do not kill the buds, but damage them so far that the leaves, when they open, are crinkled and curled. Later they attack the open leaves and frequently the stalks of the leaves, which then die. The larvæ attack both leaf and blossom buds, but the latter are especially chosen, and a tree attacked by this pest seldom produces any fruit. The leafage that comes after an attack may be irreparably

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[a] The Pear-tree Psylla. Bul. 44, Cornell University Experiment Station, 1892.

[b] Insects Injurious to Gardeners, Farmers, etc., p. 270. (Trans. J. and M. Loudon.)

damaged, but I have during the past year seen it completely recover. This no doubt was due to the abnormally wet summer we have had.

The winter is passed in the egg stage, chiefly on the young shoots, and thus it may be transported from one country to another very easily.

LIFE HISTORY.

The adult insects are about one-eighth of an inch in length and at first are pale apple green in color, but as the autumn advances they become varied in color, some reddish, some still green, others mottled with yellow, and others pale green with red or brown markings; the wings are veined in the typical way and are transparent, and sometimes they are iridescent, the veins being pale yellow or green. The adults occur from July until even November and live on the leafage of the apple, where they frequently occur in little colonies, but they soon disperse if the tree is jarred, and move with that characteristic jump and flight common to this group. I have never noticed the adults doing any damage to the leaves, but Miss Ormerod states that "they may be found in parties of five or six on a leaf, especially on a yellowing leaf," which looks as if they may do some harm to the foliage. Egg laying commences soon after pairing and may go on until as late as the end of November, but such is unusual. The females mainly deposit their eggs among the fine hairs of the young shoots, but they may be observed in cracks and crevices of bark. Generally several are laid together and then usually in rows, end to end. The eggs are roughly spindle shaped and white in color, and apparently have one end slightly prolonged, but not as in the pear psylla. As many as 20 or 30 may frequently be counted on a shoot. They remain in this condition all the winter, and I have found many are killed by an application of caustic alkali wash, and this probably furnishes a reason why the pest has not been so harmful where the orchards were usually sprayed with this wash,[a] and occurred in numbers again when this useful orchard treatment was given up.

As soon as the apple buds commence to swell in the spring, the larvæ come from the eggs and soon work their way into the buds. If the buds develop rapidly the leaf and blossom come out and are only stunted; but if the nights are cold, and growth is retarded, they may be killed entirely. During the past year the larvæ were noticed in the opening buds early in May, and they were all in the pupal stage in the second week in June. The larvæ at first are dirty yellow, with brown and dark spots upon them, the tarsi brown and the eyes red; in general form they are flat. After the first moult the larva protrudes a small white opaque globule, which remains attached by a white or pale blue thread. Soon after the second moult the larva becomes pale

[a] Second Report Economic Zoology, p. 50—F. V. T.

green, and there are formed by it a number of tangled white threads. In about another week a third moult leads to the pupal stage. In this the wing-buds are very prominent, and the tips of the antennæ and the eyes become black. Like the larva, the pupa passes out the same oily globules and waxy white or blue threads. Those kept under observation on a tree hatched on the first of June, and they remained until the end of the month. The adults pass a monotonous life on the apple trees. I have also found great numbers of this pest in the winged stage by beating hawthorn hedges in the neighborhood of infested orchards. A well-known fruit grower in Kent tells me this pest also attacks the buds of his cobnuts and filberts. It will thus be seen that there are two ways in which this pest may reach America. Taschenberg inclines to the belief that there is a second brood, but I have been unable to trace one in Great Britain, and Schmidberger does not hint at it. The pest has certainly been distributed about England with infested nursery stock, and I see no reason why it should not find its way to the American Continent and the British colonies. The only preventive we find of any use is spraying with quassia and soft soap as soon as the buds commence to swell and the larvæ are seen to be coming from the eggs. This must be done repeatedly, as the brood lasts some time in hatching out. Late autumnal washing with the usual paraffin emulsion I have found kills the adults and so prevents egg laying. We usually use 6 to 8 pounds of soft soap, 8 pounds of boiled quassia chips to the 100 gallons of soft water.

Carbolic, at the rate of 2 to 3 gallons to 100 gallons of soft water, in which is dissolved 6 pounds of soft soap, has also been found beneficial, and winter washing with caustic alkali wash has given relief.

THE CURRANT BUD MITE.

(*Eriophyes ribis* Nalepa.)

In many districts of Great Britain black currant growing is being stamped out by the enormous increase of the black currant mite (*Eriophyes ribis*), formerly known as *Phytoptus ribis* of Nalepa. This mite produces the disease known as big bud in black currants. It has practically invaded the whole of Kent, and scarcely a plantation is to be found free from this acarus, acres and acres being grubbed up in consequence. There are, nevertheless, regions free from *Eriophyes ribis*, notably the north of Ireland, in Armagh and County Down. In England Northumberland is free; Derbyshire, and a few other counties comparatively so. On the Continent Holland is particularly invaded. The disease has been mainly spread by means of infested cuttings and young bushes. At one time it was thought in this country that the swollen buds were natural, and that they showed strength, and in this way big budded plants were sent out in preference to those with normal healthy ones. It is no new pest in Great Britain, for in the neighborhood of Maidstone, Kent, it was noticed more than sixty years ago. It did a good deal of damage in Scotland in 1849 and 1850. The first record I know is that which appeared in the Gardener's Chronicle in 1869. Bushes that are attacked can easily be told by the large swollen buds; some of these will be seen dead and brown on an invaded bush; others green yet unopened; others may burst and give out leaves. Fruit buds mainly seem to be attacked, and a bush so infested seldom bears any currants. Mr. E. J. Lewis, the chief authority on this pest in Europe, has, however, observed that now and then diseased buds may burst and bear fruit, but such is very unusual. A bush may have a few or all the buds swollen according to the degree of attack. Infestation seems to begin at any spot; sometimes it shows first at the terminal buds; at others half way up, but most occur at the base of the shoots. The difference between normal and diseased buds is very marked when they are compared; normal buds are conical, whilst infested ones are more or less globular and have a somewhat mealy appearance, and on being opened they are of an unhealthy and pale color, and the mites may be easily seen within with a lens. Hundreds of mites occur in each infested bud, and among them their gray eggs and the young acari.

LIFE-HISTORY OF THE MITE.

The *Eriophyes ribis* when mature reach 0.23 mm. in length; they are narrow and elongated and somewhat cylindrical, usually curved, and vary in color from dull shiny white to pale creamy yellow. Now and again specimens may be seen with a green dorsal line, due to the chlorophyl they have eaten showing through the integuments. The skin is marked with transverse rings, 60 to 70 in number, each having a band of round processes. On the body are five pairs of bristles disposed as follows: The first on the ventral surface midway between the legs and the second pair of bristles; the second much longer and placed just before the middle of the body; the third pair very short and placed more ventrally; toward the apex another rather longer pair, also ventral; the fifth pair are lateral on the apical segment and are the longest. The legs, as in all the Phytoptidæ are four in number placed on the anterior moiety of the body. The basal joint is small, the second has a small bristle, the third has a long one on the upper side, another is present on the upper side of the fourth, and two on the terminal segment, the longer on the outer side near the base; this last joint ends in a lateral curved, long, blunt claw and a terminal bristle with five lateral processes on each side of it.

The mites live and breed in the buds all the year. The male is smaller than the female. The eggs are large, shiny or glassy bodies, varying in color from white to pallid green. The latter color is given by Mr. Lewis, but I have never seen them this color myself. There is no time during the year in which the reproductive powers are checked as long as the weather is more or less congenial. Mr. Lewis found the eggs fewest in December and January, but during the present year they have been teeming in the buds during the first two weeks of this month (December). No doubt frosty weather checks the reproductive powers. Certainly the increase is most rapid from April to October. When the buds burst in April, the Phytoptids may be seen crawling outside, and as pointed out to me by Mr. Lewis, they attach themselves by the anal sucker and wave their bodies and legs in the air. Mr. Cecil Warburton states that they jump into the air. This is extremely probable, but that they do so to chance falling on to a passing insect so as to be distributed is very problematic.

The life cycle can and does go on from year to year on the bush; when a bud is killed or when it bursts the mites crawl out and make their way to others. This is not all, however, for if we cut down a bush that has been badly attacked we still find next year's shoots showing traces of big-bud and the swollen buds occur low down the shoots. This, I am sure, points to infection coming from the soil. Whether eggs or mites or both retain their vitality in the earth I do not know, but that they contaminate the soil I am fully convinced. Hence we find hand picking and hard pruning only partly successful.

Certain varieties are more susceptible than others, but none except a light-cropping cottage black currant grown in Kent seem to be immune. The Baldwin is the worst sufferer; then come Black Naples and Black Dutch. Lee's Prolific is also attacked, but clean stock of this kind can be procured. Carter's Champion is thought to show some degree of immunity. I do not think any black currant will long resist this pest, which spreads rapidly, being distributed by men walking in the plantations, the mite becoming attached to their clothes, or in mud on their boots. Many no doubt are carried by the wind and numbers by other insects, especially bees of the genus Andrena and Bombus that visit the currants when in blossom.

PREVENTION AND REMEDIES.

With regard to this serious pest, we have tried many things. At first fumigation, with hydrocyanic-acid gas, was considered useful, but later it was found to only be partially successful, and that as the mite increased so rapidly it was of little use. Moreover the gas does not affect any mites in the ground, and if there is any moisture on the buds it affects the mite scarcely at all. In fact, even for cuttings and young stock, it is of little value. I believe hydrocyanic-acid gas is valueless for all acari. A new method of fumigation is being tried by Mr. Wilcocks of the S. E. Agricultural College, which so far seems successful. Should it prove so I shall at once forward the results.

All we can do at present is to grub up all infested plantations and start on fresh land with guaranteed clean stock.

Various sprays, and in fact all known methods of treatment have been found ineffectual.

These, I consider, three very important European fruit-tree pests to be kept in mind, not only because they can easily be imported, but because all three are very difficult to fight, and the last mentioned has so far baffled all attempts to destroy it.

THE CHERRY FRUIT FLY.

(*Rhagoletis cingulata* Loew.)

By F. H. Chittenden.

During June, 1901 and 1902, Dr. A. M. Farrington, of the Bureau of Animal Industry, furnished a lot of cherries infested by a maggot

Fig. 17.—*Rhagoletis cingulata*: *a*, fly; *b*, maggot from side; *c*, anterior spiracles of same; *d*, puparium; *e*, posterior spiracular plates of pupa; all enlarged (original).

which was subsequently reared by the writer, and proved to be *Rhagoletis cingulata* Lœw. Injury had first been noticed in 1899 and had been continuous since that time. About two-thirds of the cherries on his place in the District of Columbia were destroyed in 1902. Injury was seldom detected until the third week of June, when the cherries were ripe. In our rearing jars the flies issued through the month of April of the following years, but from the fact that the larvæ attain full growth by the beginning of the last week of June, there can be little doubt that the flies issue normally during the latter part of May or early June. Attack was noticed only to Montmorency cherry, a nearly black variety, with a sour and rather unusually strong Prussic-acid flavor. There can not well be more than a single generation of this species on cherry, the larvæ leaving the fruit during the last week of June and first of July, and remaining in the earth until the following spring or early summer. During the season of 1903, Dr. Farrington reported a complete disappearance of this species from his vicinity, and Prof. M. V. Slingerland, who has studied the species in New York, noted a similar lack of injury in the neighborhood of Ithaca, N. Y.

PROBABLE EXPLANATION OF THE INSECT'S DISAPPEARANCE.

To explain this disappearance the following reasons present themselves. Assuming the natural time for the appearance of the flies in the District of Columbia to be toward the end of May or first of June, the weather that was encountered during 1903 at this time was unusually cool and will doubtless explain the practical extirpation of the species temporarily and locally. In other localities similar adverse atmospheric conditions prevailed which might have produced the same effect. A cold wave was experienced in the latitude of Washington in the last week of April, causing some loss to early vegetable growth. During the third week frosts were prevalent, which also had a damaging effect on susceptible crops. Frosts also occurred during the last week of April. In short, the spring was late for this section. The first three weeks of May showed drought in many sections, and frequent temperatures from 85° to 90°, and nearly 100 during the third week, the end of the month turning cloudy and cool, after which showers were of almost daily occurrence, accompanied by thunder, hail and high winds, these conditions continuing practically throughout the entire month of June.[a] That undue dryness usually causes retardation in development is an established fact, hence there is little doubt that the dry weather had the effect of preventing the metamorphosis of this species, until frost and dampness ensued at exactly the time when the fly should have issued from its puparium, with the result of its destruction in great numbers.

EARLIER RECORDS OF INJURY.

July 17, 1899, we received the same species from the Hittinger Fruit Company, Belmont, Mass., then in the larval condition, with statement that cherries there were very generally affected.

During the same year, as also in 1900 and 1901, this species attracted considerable attention at Ithaca and Geneva, and elsewhere in New York, as recorded by Professor Slingerland in Bulletin 172 of the Cornell University Agricultural Experiment Station. This simultaneous outbreak of a species hitherto unrecognized as noxious in New York, Massachusetts, and the District of Columbia is quite remarkable. A reported case of injury in northern Michigan in 1889, just ten years earlier, is attributed to this species, and probably correctly

[a] See Weekly Crop Bulletin, Maryland and Delaware Section, Climate and Crop Service of the Weather Bureau, of this Department.

(A. J. Cook, 2d Ann. Rept. Mich. Expt. Sta., p. 153), while other reports have been made of destructive occurrences from three to five years earlier at Bonaparte, Iowa; Westboro, Mass.; Batavia, Portland, Cattaraugus, Clifton Springs, Syracuse, and Cayuga, N. Y., and State College, Pa. In two of these localities injury of a similar nature had been noticed as early as about 1865.

It is highly probable that the same species has been destructive for generations in many other localities than those mentioned, but the cause of the trouble has without doubt been undetected, because attributed to that more common and nearly universal cherry pest, the plum curculio.

As this cherry fruit fly has not received notice in any publication of this office, an illustration of the different stages is presented, as also one of the plum curculio (*Conotrachelus nenuphar*—fig. 18) that the two species may not be confused.

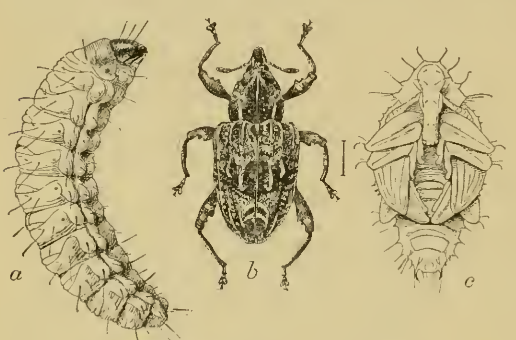

FIG. 18.—*Conotrachelus nenuphar: a*, larva; *b*, beetle; *c*, pupa—all much enlarged (original).

DESCRIPTIVE.

The adult.—The cherry fruit fly is closely related to the apple maggot (*Rhagoletis pomonella*), and might readily be mistaken for that species in all of its known stages. It is, however, a little smaller, and in the adult or fly stage much paler in color, but the wings are similarly banded. The body is piceous, the head and legs pale yellowish brown, the eyes dark greenish, the thorax striped, with the sides marked with a broad longitudinal yellow band, and the abdomen is strongly segmented, due to transverse pale brownish stripes. The wings are somewhat faintly banded with dusky color arranged about as shown in fig. 17, *a*. The body, including the head, is about one-sixth inch in length, and the wing expanse is three-eighths inch.

The egg, as described by Lowe, measures 0.02 inch, is somewhat broader toward one end, and about one-fourth as wide as long at the widest point. "Beginning at the broad end and extending about one-fourth the length of the egg the shell is roughened and somewhat darker; color a dirty yellow."

The maggot or "worm" is so nearly an exact counterpart of the apple maggot that a technical description is omitted. The color is yellowish white, and the form is shown, lateral view at fig. 17, *b*. Near the head there projects on each side a small pale brown somewhat fan-shaped organ, the anterior spiracles (fig. 17, *c*) of which have many minute branches. The mouth parts, as in most maggots of this character, consist of two minute, sharp, black rasping organs, which answer the purpose of mandibles and which project slightly from the head. The length when mature is one-fourth of an inch.

The puparium or quiescent stage is represented by fig. 17, *d*. It is dark brown in color and of moderately strong consistency.

The distribution has been practically given in the list of localities in which injuries have been noted. It might be defined as extending from Massachusetts and New York southward at least to the District of Columbia, and westward to northern Michigan.

LIFE HISTORY.

The life economy of this species is fairly well understood, owing chiefly to the observations of Mr. Slingerland, but some details remain to be observed.

The egg is deposited just underneath the skin by means of the ovipositor, may be placed in any portion of the cherry, and the egg scars, although not in crescent shape like those of the plum curculio, are easily discovered. Throughout the northern range of this insect, where it is most injurious, oviposition continues over a considerable period, from June until into August, or probably as long as cherries are to be found. Unhatched eggs have been discovered as late as August 16. The exact period of the egg stage has not been observed, but it will probably extend from three or four days to a week or ten days, according to temperature. Soon after hatching the larva penetrates to the vicinity of the pit, feeding on the flesh and forming a rotting cavity similar to that made by the larva of the plum curculio. As a rule the maggots attain maturity simultaneously with the ripening of the cherries, and they thus find their way to the consumer. It has been observed that few affected cherries fall from the trees, in which respect this species differs from the apple maggot. The maggots, therefore, usually drop to the ground, where in a few days they form the puparium stage.

The species is without doubt single brooded, even as far south as the District of Columbia, and probably as far as its southern range extends, and the pupal period therefore consumes about eleven months of the year, this stage being passed in a cell within about an inch of the surface of the ground. As it frequently happens that infested cherries show little exterior effects of damage they are shipped from one locality to another, and the insect can thus readily obtain a footing in new localities; but being a native species, this is a matter that probably has little importance.

As to the varieties of plants affected, thus far there is little doubt that the insect affects chiefly sour or subacid varieties, particularly the Morello and Montmorency varieties, but the Downer and black cherries are also subject to attack; in fact, no varieties are positively immune. It is probable that the species lives normally on some sour species of native cherry, and if such should prove to be the case these trees should be destroyed or the fruit carefully picked if it have any commercial value.

METHODS OF CONTROL.

The brief account furnished of the life history of this species is indicative of the difficulty of destroying it or preventing its ravages. We can not destroy it with insecticides or capture it by jarring, as in the case of the plum curculio, nor by gathering the "windfalls," as for the related apple maggot. The egg being inserted under the skin and the larva feeding still deeper in the fruit, can not be reached, nor can the fly, which does not feed to any appreciable extent, if at all, on the fruit. This leaves the pupa stage as the only vulnerable one for attack, and the skin of the puparium is so compact that it is probably impervious to any ordinary liquid which would not injuriously affect the tree or the soil.

The most feasible remedy that suggests itself is careful cultivation of the orchard, but this has been practiced by some of the most successful orchardists of New York, and injury was evidently not lessened thereby. An explanation urged by Mr. Slingerland is that the puparia are too small to be crushed, and it is therefore suggested that remedies advised for certain species which have similar habits and infest currants, be employed, remedies which have been advised for years in this Department. These consist in late fall or early spring plowing, so deeply that the puparia will be buried far enough beneath the surface as to render it impossible for the flies to emerge. Where a few valuable trees only are affected the surface soil could be removed to a depth of about an inch or a little more, and either thrown loosely into a hen yard or upon a much traveled highway, or buried deeply, all of which methods would insure the death of the puparia.

Hens have been observed to destroy the puparia, and if the soil under the infested trees were lightly raked and temporary wire nettings were placed around the trees, hens could be confined in this inclosure and would soon destroy the pest.

Clean culture must, of course, be observed, which would include the picking of all of the cherries from the trees, and the destruction of such few windfalls as might be found.

In conclusion, it should be stated that various other remedies than those mentioned have been tried without success in other countries against insects of similar habits. These include attracting to lights, the use of deterrent substances to prevent the flies from ovipositing, spraying with a great variety of insecticides and other substances. Of these one is deserving of mention, a mixture of sulphur and caustic soda in solution, which gave partial success.

One orchardist reported that some success was attained by the use of sticky fly paper, the flies being attracted to anything shining, such as a straw hat.

A perfectly effectual method of preventing attack by a fruit fly in south Africa, but one which would scarcely be used save in the case of the most valuable trees, consisted in inclosing the entire tree above the trunk in a fine-mesh mosquito netting during the time when flies are abundant.

It is quite possible that Morello and Montmorency cherries might be grown in districts where these flies are abundant, as traps to lure the insects from other varieties of trees. This method is certainly worthy of trial. On these trees the fly paper could be used, and considerable expense could thereby be saved.

Finally, would-be growers of cherry, in the regions which have been noted as the seat of the principal outbreaks of this fruit fly, are cautioned against the planting of Morello, Montmorency, and similar sour varieties as a main crop, owing to the greater liability of injury by the pest.

ON THE ORIGIN OF THE NATURAL COLORATION OF SILKS OF LEPIDOPTERA.

By G. Leverat and A. Conte.

(Comptes Rendus, de l'Académie des Sciences, read October 27, 1902.)

With most lepidopterous larvæ the product of the silk glands is not colored. When it is colored it is yellow or green. We ask ourselves, what is the origin of these green and yellow pigments? Are they made by the animal or simply drawn from the leaf upon which it feeds? The first of these hypotheses has been generally held since the work of Alessandrini Joly, R. Dubois, and L. Blanc have shown that it was impossible for a coloring matter contained in the intestine to reach the silk. The contrary results obtained by Bonafous, E. Blanchard, Roulin, and Villon have been denied in an absolute manner and stated to be the consequence of a soiling of the silk thread on its exit from the spinneret. If the coloring matters employed so far do not easily pass through the walls of the silk reservoir, is it the same for all of the coloring principles and for all silkworms? It is to respond to this question that we have undertaken our new experiments. Our trials were carried on with a wild silkworm, *Attacus orizaba*, and the domesticated silkworm (*Bombyx mori*), the French race with yellow silk, and a polyvoltine race from China with white silk. The coloring matters used were neutral red (toluylene red), methylin blue, B. X., and picric acid.

(1) *Attacus orizaba.*—Thirty larvæ born July 16, 1902, were divided into several lots and raised upon oak branches, of which the leaves had been washed with an aqueous solution of coloring matter.

In one lot nine caterpillars were fed from their birth upon leaves impregnated with the neutral red. They ate these leaves without showing any repugnance and developed normally. The general reddish tint of the body indicated the presence of the coloring matter in the blood.

For the purpose of avoiding all possibility of soiling the silk the larvæ at the beginning of cocoon spinning were carefully washed with a stream of water and carried to freshly collected branches. The silk coming from the spinneret is tinted with rose, and the whole cocoon presents a beautiful red coloration.

Two caterpillars of this lot were isolated at the fourth molt and nourished during the last age with leaves deprived of the red coloring. These caterpillars faded and the silk which they spun was scarcely tinted with rose.

Four other caterpillars having eaten natural leaves up to the fourth molt, then received a colored nourishment during the fifth age only, and furnished cocoons as red as those of the first lot which had absorbed the red during the whole larval life.

Caterpillars raised upon methylin blue seemed to eat the leaves with less avidity, their development slower, and they secreted a less abundant silk, which was slightly bluish.

Finally, the last lot of *Attacus orizaba*, fed upon leaves washed with a solution of picric acid, gave cocoons with white silk.

Thus we see that the neutral red passes easily by osmosis through the tissues, while the methylin blue passes through only with difficulty, and the picric acid is completely arrested. In order to reply in the most perfect way to the criticism based upon the hypothesis of the superficial coloration of the silk thread from the possible soiling of the silk, we have taken two caterpillars and injected the neutral red in the next to the last left proleg. These caterpillars were instantly colored with red without appearing in the least incommoded, and spun a slightly rosy silk.

(2) *Bombyx mori.*—The same experiments were made upon the two races of *Bombyx mori*, the one with yellow silk and the other with white silk. In the two cases the caterpillars became colored with violaceous red immediately after the first meal, and gave a bright orange yellow silk in the first case, and a beautiful pure rose for the white race. The color became accentuated according to the duration of the feeding of color food.

This fact demonstrates that the passage of the coloring matter into the silk gland is less easily made than with *Attacus orizaba*. Will the result be the same after several generations submitted to this artificial régime? That is what we intend to find out. From these researches the possibility of making a substance coloring matter, for example, pass from the digestive tube to the silk by means of the blood, is established. This conclusion permits us to search for the origin of the natural color of silk in the green coloring matter of the leaves.

The silk is white because no coloring matter has been able to pass through the walls of the silk gland. In the green silks it is the chlorophyl of the leaves which passes through. We have, in fact, proven that with a species which has green silk (*Antheræa yama-mai*) the blood has the chlorophyl spectrum. The yellow pigment contained in the blood of the yellow species is identical, as has already been shown by R. Dubois and L. Blanc, with that of the mulberry leaves, and comes directly from these leaves.

It is not to be supposed that the coloring matter of silks can be made with the animal itself, as the negative results of attempts with artificial coloration have shown.

SOME PRELIMINARY NOTES ON THE CLOVER-SEED CHALCIS-FLY.

By E. S. G. Titus.

During the latter part of the past summer a study of the life history of the clover-seed chalcis-fly was taken up, and in answer to letters sent to several correspondents of this office there were received packages of ripe and ripening cloverheads from various localities in the United States. Clover heads were also received from various other sources. The majority of these were found to be infested with the clover-seed chalcis-fly (*Bruchophagus funebris* How.), by the clover-flower midge (*Cecidomyia leguminicola* Lint.), and in several instances both insects. The chalcis-fly was reared from clover heads from the following localities, the name in parentheses indicating the collector of the clover heads: Hanford, Cal. (F. Benton); Fort Collins, Colo. (L. A. Titus); Marengo, Ill. (E. M. Wright); Urbana, Ill. (F. M. Webster); Winona Lake, Ind. (F. Benton); Richmond, Kans. (E. C. Gentry); Agricultural College, Michigan (R. H. Pettit); Agricultural College, Mississippi (Glenn W. Herrick); St. Anthony Park, Minn. F. L. Washburn); Quaker Street, N. Y. (C. H. Moore); Corvallis, Oreg. (A. B. Cordley); Providence, R. I. (F. C. Pratt); Burlington, Vt. (G. H. Perkins); Pullman, Wash. (C. V. Piper); Danville, Va., Virginia Beach, Va., and District of Columbia.

From some alfalfa seed from Mr. L. L. Marsh, Enosburg Falls, Vt., received through the Bureau of Plant Industry, three specimens of this chalcis-fly were reared.

In order to obtain with any certainty the full life history of these species it was necessary to rear them isolated from each other. A small area of clover, growing wild in the Rock Creek bottoms, was selected and several clover plants were covered with breeding cages. All budded and advanced flowerheads were removed. Owing to the late date at which the experiment was started only a few more heads formed. After blooming was well advanced fertilization was effected by the introduction of various insects, no attempt being made to determine which particular species accomplished the desired work. Adults of the chalcis-fly (*Bruchophagus funebris*), were later introduced, after the corollas of the flowers were well formed. These insects had been selected from lots reared from clover seed taken in Washington, D. C. Damage by rain ruined many heads and others failed to mature, but in the end several heads became sufficiently matured to be picked, and from these there were secured late in the fall a few adult individuals of the chalcis-fly. Very few of the seeds in the heads developed.

The egg was usually laid in the young forming clover seed. It is apparently inserted *into* the seed beneath the cuticle. The egg is pale white, polished, slightly elongate, and rather slender in form, no trace of sculpturing being seen.

The larva seems to feed on the softer semiliquid portions of the seed and does not attack the essential organs until nearly mature. As it grows it fills about two-thirds of the interior of the seed, curving itself into the wider portion. When nearly mature the larva finishes the seed contents, practically filling the cavity and then pupates. The full-grown larva is pale white from 1.5 to 2^{mm} long. When mature, rather stout, the ridges on the segments quite prominent.

The pupa, at first pale white, changes in color to a deep brown as it matures, and the adult insect, when it emerges from the seed, is shining jet-black with white markings, which latter soon change to deep yellow.

The adult emerges from an irregular hole cut in the seed, usually in what is the upper portion as it stands in the head. I have, however, found the hole cut in various other places. Further rearings will be necessary before any statement regarding length of life in various stages can be made.

Several instances were noticed when for some reason the seed failed to develop (perhaps because utterly destroyed by the young larva), and the larva had made its way through the soft tissues and entered another seed, there finishing its growth. In one instance three seeds were found partly devoured, apparently by the same larva.

A number of parasites were reared from the clover heads received from the various localities, but at present I am unable to definitely state which enemy of the clover head was parasitized by them. One specimen of *Bracon mellitor* Say was reared from a head taken at Washington, D. C. This parasitic insect has hitherto been recorded only from Coleoptera. It could not be determined from what it bred in this instance, but a single coleopterous larva might easily have been present.

The chalcis-fly conducts its ravages in such an insidious manner that the losses occasioned by it are scarcely recognized, the scarcity of seed at the time of hulling being usually put down as caused by the clover-flower midge.

Heads attacked by this latter insect fail to flower properly, and can be easily recognized in the field by the lack of flowers in all or a portion of the head. Where only a portion of a head is attacked it becomes dwarfed and contorted, the undisturbed florets going on and maturing their seed.

Heads attacked by the chalcis-fly do not apparently differ from sound heads, and seed becomes sufficiently mature before the adult insect emerges to allow it to hull out when thrashed. These light shells are of course instantly swept away in the cleaner, and the grower has no means of ascertaining the true cause of the shortage of the crop. In a large number of heads examined, selected at random from various lots, the percentage of injured seed varied from 40 to 85 per cent, the average being fully 50 per cent to a head. There are at least two generations of the chalcis-fly during the year, the second wintering both as larva and pupa in the seed.

This species was originally described in 1879 by Dr. L. O. Howard as *Eurytoma funebris*.[a] The types were males and females bred from clover in heads, and at that time were presumed to be parasitic on the clover-flower midge (*Cecidomyia leguminicola* Lint.). Dr. W. H. Ashmead, in 1894,[b] referred the species to a new genus which he named Bruchophagus, believing the species of this genus to be all parasitic on the seed weevils (Bruchidæ).

At present the genus contains, besides *B. funebris* How., the species here treated: *Bruchophagus borealis* Ashm., reported by W. H. Harrington from Canada as bred from *Bruchus* sp.; *B. mexicanus* Ashm., reported by "Prof. Tyler Townsend" from New Mexico as bred from *Bruchus scutellaris* Horn [= *chinensis* Linn.] and *B. herreræ* Ashm., originally sent from Mexico by Dr. A. L. Herrera, who stated that it bred from the cotton-boll weevil (*Anthonomus grandis* Boh). Thus far no Bruchus is known to naturally attack clover seed in this country, and it would seem that the clover-seed chalcis-fly, if ever a coleopterous parasite, has changed its diet. A more complete study of the other species of the genus and future rearings may prove that all are simply true seed-miners.

Nothing further was published on this chalcis-fly until 1895,[c] when Dr. A. D. Hopkins, at the eight annual meeting of the Association of Economic Entomologists, reported finding (June 13) numerous chalcis-flies on and in a paper bag in which were stored ripened heads of crimson clover. The flies proved to belong to this species, and Dr.

[a] U. S. Dept. Agr. Rpt. 1879, p. 196.

[b] Trans. Amer. Entom. Soc., v. 21, 1894, p. 328.

[c] Bul. 6, n. s., Div. Entom., U. S. Dept., Agr., 1896, p. 73.

Hopkins stated that observations led him to believe that this fly was more destructive to growing red and crimson clover seed than the midge. He also noted that while the midge actually prevented the seed from forming, the chalcis-fly fed in the developing seed and allowed it to almost reach maturity before entirely devouring the seed content. The following year, at the next annual meeting of the same association,[a] Dr. Hopkins reported that his studies of the year left no doubt "of the chalcis-fly being a destructive enemy and that it wintered out of doors in the seed as a larva."

Lintner, in his report as State entomologist of New York, for 1896, credits the clover injuries reported by a correspondent of his office, "J. W. J., Muncie, Indiana," to the clover-seed worm *Grapholitha* (*Enarmonia*) *interstinctana* Clem. The description of the injury as reported by the correspondent, "seeds hulled out like beans eaten by bugs" would indicate the work of this chalcis-fly rather than that of the seed worm.

LIFE HISTORY OF THE SALT-MARSH CATERPILLAR (ESTIGMENE ACRÆA DRU.) AT VICTORIA, TEX.

By W. E. Hinds.

While stationed at Victoria, in 1902, there were brought to the headquarters of the boll-weevil investigations during the last part of July and first of August numerous reports of very serious damage to certain fields of cotton which, it was said, were being entirely stripped of leaves by a very "large black caterpillar." One of the remarkable "facts" reported in regard to this strange caterpillar was that "it could not be poisoned." Nothing seemed effectual in stopping the progress of the worms, and the foe was thought by some to be "worse than the boll-weevil." As soon as the larvæ had stripped one field, it was said, they would move in vast numbers to fresh fields where they would repeat their work of devastation.

So alarming were the reports and so urgent the appeals to the boll-weevil investigators, that on August 5 an examination was made in the infected territory. It was found that the damage was being done by the larvæ of *Estigmene* (*Leucarctia*) *acræa* Dru., the "salt-marsh caterpillar," so called because at the time it was first described the larvæ were overrunning the salt marshes in the vicinity of Boston, Mass. The larvæ had nearly completed their feeding when found and a large part of them had crawled out of sight into favorable places for pupation. The thin cocoons, made by interweaving the long hairs from the body with a light web of silk, were found at the surface of the ground under some sort of rubbish. As a rule about one-half of the cell was formed as a lining to a corresponding depression in the earth. A large

[a] Bul. 17, n. s., Div. Entom., U. S. Dept. Agr., 1897, p. 45.

number of caterpillars was taken to the laboratory, where they could be watched and the general facts of their life history determined. All the larvæ spun up within five days after being taken from the field. The average length of the pupal stage was about two weeks, varying only a few days in any case. As the moths were found to be depositing eggs it was thought best to follow the life history of the following generation.

The eggs with which these studies were started were brought from the field on August 21. They formed a compact group nearly an inch across, being placed closely side by side upon the under surface of the cotton leaf. The number of eggs deposited in a group varied, some having been found numbering between 900 and 1,000.

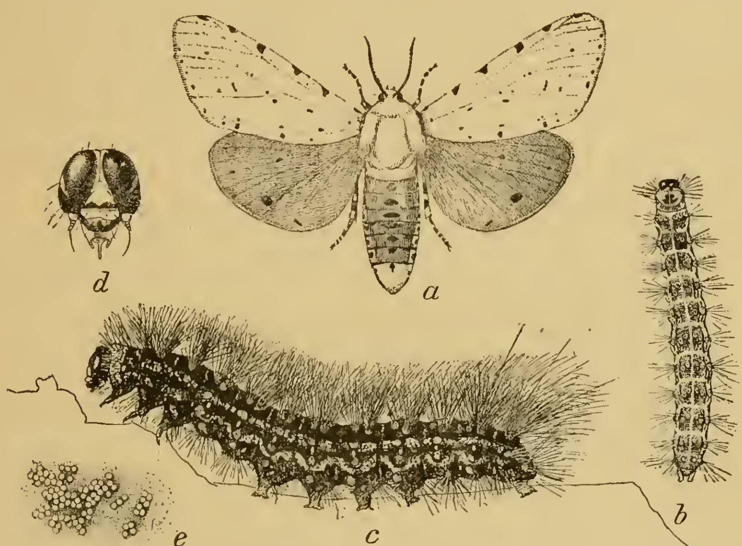

FIG. 19.—*Estigmene acræa*: *a*, male moth; *b*, half-grown larva; *c*, mature larva, lateral view; *d*, head of same, front view; *e*, egg mass—all slightly enlarged except *d*, more enlarged (from Chittenden).

EGG.

The eggs were nearly round, about two-thirds of a millimeter in diameter, and, when first deposited, of a pale yellow color. The surface of each was slightly granular in appearance. As the embryo became nearly developed the color of the egg changed to a dull blue, with a black spot near the middle of the top. Hatching occurred in four or five days. The percentage failing to hatch was very small and no parasites were developed in this lot of eggs.

LARVA.

As they left the eggs the larvæ were about 2.3^{mm} long. Their color was a uniform dark brown, and the length of the hairs was nearly equal to that of their bodies.

The newly hatched larvæ were placed upon fresh, tender cotton leaves and began at once to feed, eating only part way through, so as to leave intact the epidermis on one surface of the leaf. As a rule they chose the under side, probably in part for protection and in part because of the more tender tissue on that side. The length of the body during the first larval stage increased to about 10^{mm} and the color became yellowish brown.

In the second stage of the larva the coloration appeared more clearly. The subdorsal tubercles became black and prominent. There was an interrupted white dorsal stripe and lateral stripes of a tawny yellow color. The hairs were long and black. As the second molt was approached the subdorsal dark stripe became lighter in color and the black tubercles standing therein appeared more prominent. The length of the second stage varied between four and seven days, and during this time the length of the body increased to about 15^{mm}. Feeding was almost entirely confined to one surface of the leaf throughout this stage. This habit of feeding only upon one surface of the leaves easily explains the failure to poison the caterpillar which was at first reported.

At the beginning of the third stage the color of the larvæ appeared markedly darker than in the second. The subdorsal stripes, especially, were very dark, though the color was somewhat variable as it is in all stages. During this instar the larvæ began to consume the entire leaf tissue, that is, they ate clear through instead of leaving the epidermis upon one side. Midribs and heavy veins alone were left. The length of the stage varied between six and ten days. The length of the larva's body increased to more than 30^{mm}.

The fourth and fifth stages showed little change in general appearance. All the specimens bred were dark, while many found in the field were much lighter, and some which seemed to belong to the same species were of a bright, uniform yellow color. The length of the fourth stage varied between five and nine days and the average length of body became about 45^{mm}. The duration of the fifth stage varied between eight and twelve days and the length of the body averaged about 55^{mm}.

The entire time of the larval stage was found to vary between the extremes of twenty-four and thirty-seven days from the hatching of the egg to the spinning up of the larva. The mean average temperature for this period was about 82.8° F., or almost 40° of effective temperature.

PUPA.

Pupation took place in about two days after spinning. The cocoons averaged about 30^{mm} in length by 10 to 12^{mm} in breadth. The length of the pupal stage, or from the spinning of cocoon to the emergence of the adult, varied between nine and sixteen days, in most cases being about twelve or fourteen days. The time required for the emergence of males seemed to average about one day shorter than that for females.

ADULT.

The moths of this species measure from 1 to 1¼ inches in length with the wings closed. The predominant color as seen from above is white with prominent black spots scattered over both the upper and under surfaces of the wings and in six rows, three ventral, two lateral, and one dorsal, along the abdomen. In the female the wings are white upon the under as well as the upper sides. The back of the abdomen, with the exception of the first and last segments, is of a brownish yellow color. In the males the under surface of the forewings, both surfaces of the hindwings, and the predominant color of the abdomen is brownish yellow, thus making the distinction of the sexes a very easy matter.

GENERATIONS.

The average time required for the development of this generation was very nearly forty-five days. The adults, all of which emerged, mated within a few days and the females deposited their eggs in the breeding cages. No attempt was made to breed another generation, but as numerous large larvæ of this species were seen early the following spring, it appears that a fall brood of larvæ is normally developed and that this brood hibernates in the larval stage. No adults were seen early in the spring of 1903. Hibernated caterpillars taken into the laboratory spun up about the middle of May.

In 1902; the eggs for the generation of worms which did so much damage during the latter part of July must certainly have been deposited by the last of June, and it is very probable, though the actual fact has not been established, that the adults depositing those eggs had come from hibernated caterpillars. Assuming that to have been the case, the normal number of generations for this insect in that locality is three. The period during which the life history was followed in 1902 was exceptionally hot, and it is therefore safe to say that the normal developmental period for each summer generation is about seven weeks.

It is believed that in the Middle States this species has two generations and in the New England States it has been found to have but one.

INJURY TO COTTON.

The occurrence of this caterpillar upon cotton is by no means rare. In fact, occasional specimens may be found in almost every cotton field, but it is only very rarely that they are as abundant and inflict as serious injury as they did in the case recorded. The writer is informed by those who have seen this larva often before, that it never seriously injures cotton except in some cases where cotton is first planted upon new land.

GENERAL NOTES.

SOME INJURIOUS GARDEN AND FIELD INSECTS IN TROPICAL NORTH AMERICA.

August 16, 1903, Mr. O. W. Barrett, entomologist of the Porto Rico Experiment Station, sent specimens of noxious insects from that country which are interesting because of their relation to species known to occur also on the mainland of the United States. One of these was an unknown species of Aphis, which is stated to seriously affect squashes. A leaf-beetle, *Cerotoma denticornis* Ol., very closely related to the bean leaf-beetle of the United States (*Cerotoma trifurcata*), was said to be injurious to cowpeas. A flea-beetle, *Systena basalis* Duv., was injurious to Russian sunflower; while a leaf-hopper, *Agallia tenella* Ball., was stated to damage the leaves of beans, cowpeas, and other plants. Later, September 30, 1903, Mr. Ed. Ferrer, La Magdalena, Cayamas, Cuba, stated that *Cerotoma denticornis* did a great deal of harm to cultivated beggar-weed (*Meibomia* sp.), which also grew wild in that vicinity, from 30 to 50 per cent of the weight of the leaves being a good estimate of what the beetle devoured.

Diabrotica balteata, another leaf-beetle related to the corn root-worms was received from Mr. A. L. Herrera, City of Mexico, Mexico, with the statement made under date of December 3, 1902, that it was injurious to wheat at Salvatierra, State of Guanajuato. During July, 1903, we received from Dr. Silvio Bonansea, of the City of Mexico, a specimen of *Scyphophorus acupunctatus* Gyll., a weevil quite commonly occurring in southern California which our correspondent stated was damaging henequen (*Agave rigida*). A short account of this species and a note on the occurrence of the larva in the interior of the stems of *Agave mexicana* has been given by Dr. Eug. Dugés in the Annales de la Societe Entomologique de Belgique, 1886, p. 33. A short note on the occurrence of the adults on trunks of grape-vine at Poway, Cal., where they feed on sap, was also published, in Volume V of Insect Life (p. 35).

REMEDY FOR STORED GRAIN INSECTS IN CUBA.

Mr. Limeon Poveda, jr., owner of a breeding farm in the suburbs of San Leandro, the municipal boundary of the Cuban town of Palma Soriano, known also as San Juan, who is also engaged in the practical study of agriculture, writes as follows in regard to the occurrence of weevils in maize and the remedies to be used in combating them:

In spite of the enviable fertility of the soil, which permits the gathering of the crops in less than three months, farmers can only receive a reward for their labor and sacrifice by the immediate selling of the crop as soon as harvested, because it quickly becomes infested by the weevil, which in a few days renders it useless.

For the prevention of this damage the Department has assisted the agriculturists to make the following experiment:

When the corn is harvested and to be gathered into the storehouse, the grain is sprinkled to a height of 12 to 15 inches and then covered by a layer, nearly covering it entirely, of the sawdust of cedar mixed with a little salt (about half a gallon), followed by a thick layer of maize, then by another thick covering of the cedar dust and a little salt, continuing the same process.

This author presents the difficulty, in the practical outcome, of producing a flavor which is disagreeable to the animals and leaves them in a condition unfit for the market.

BEETLES INJURIOUS TO HERBARIUM FUNGI.

We received during March, 1903, through the kindness of Prof. T. D. A. Cockerell, from W. C. Sturgis, some interesting information in regard to injury by certain species of beetles to a collection of fungi and mycetozoa. Professor Sturgis, writing from Colorado Springs, Colo., states that his collection of mycetozoa has been much bothered by the attacks of small beetles which feed mostly upon spores, and especially of the Stemonitaceæ. He complains that some most beautiful and copious specimens were reduced to nothing but sticks and a powdery mass of black excrement within a period of a few weeks by these pests. Among the insects troublesome to his plants are the following:

Arrhenoplita bicornis Ol. Injured Stemonitis, and was alone.

Sphindus americanus Lec., very commonly met and destructive.

Liodes obsoleta Horn., also concerned in injury.

Bæocera (?) sp., also concerned in injury.

Professor Sturgis states that these beetles operate after the specimens have been dried and placed in the herbarium; that they prefer the specimen to the wood as food, and that their depredations are almost exclusively confined to the Stemonitis, Comatricha, and Lamprederma, genera whose species often show a dense tufted habit peculiarly susceptible to attack.

A fifth species, presumably a Cioid from the description, is mentioned as the principal insect enemy to the specimens which have been considered.

A WEST INDIAN FRUIT-TREE BORER.

June 8, 1903, we received a communication from Mr. Bernabe Sanchez Adan, Central Senado, Las Minas, Cuba, with accompanying specimens of the Bostrychid beetle, *Apate carmelita* Fab., which was reported to be destroying orange, plum, and almond orchards. The beetles were described as boring from the outside seeking the core, which they readily attacked, the trees perishing in a short time. By the same mail we received a second letter, from Mr. J. H. Hemenway, Cienfuegos, Cuba, containing report of depredations by this same insect on the coffee plants, it being described as very common and completely destroying plantations.

This species is mentioned in literature generally as *Apate francisca* Fab., which is a synonym of *carmelita*, the latter being the male and the former the female of the same insect. It may be remembered that a note was published on this species (Ins. Life, Vol. VI, p. 274) as boring in Lagerstrœmia in Jamaica.

SAY'S PLANT BUG.

(*Liodermu sayi* Stål.)

One of the remarkable outbreaks of the year 1903 was that of a large green pentatomid bug (*Liodermu* [*Pentatoma*] *sayi* Stål.). It was most injurious to grain, and especially to wheat, but in some cases attacked a variety of other plants. Among interesting reports of injuries received was one from Prof. C. P. Gillette, who wrote, August 19, that many wheat fields in Montezuma County, Colo., had been reduced from 25 to 75 per cent. Fields of oats were also badly injured, and in some cases beans and peas were attacked. May 9, Prof. T. D. A. Cockerell reported an outbreak in Arizona. At that time the insect was so abundant that it threatened the ruin of the grain crop in the vicinity of Pima, Thatcher, and Fort Thomas. It was noticed that the insect was common also on wild plants in that territory. At Phoenix, Ariz., and vicinity, Mr. Matthew M. Murphy reported considerable damage, especially to late wheat. Mr. C. C. Pitrat, Farmington, N. Mex., reported September 9 that this bug had caused much loss to the wheat crop of that vicinity, the bugs having first been noticed July 20, when the wheat was in the milk. Three or four bugs were found clinging to each head of wheat, seeming to suck the juice from the forming seeds. It was estimated that the bugs had badly damaged or completely ruined about half the wheat in San Juan County. It was observed that the bugs had a very offensive smell, like that of the common squash bug (*Anasa tristis*). Mr. J. J. Starley reported injury to potato vines at Fillmore City, Millard County, Utah. From specimens received from this latter source, eggs were deposited in July, and young were observed July 25. Reports of injury chiefly to grain were also received from Safford and Tucson, Ariz., and Cortez, Colo.

AQUATIC BUGS OF COMMERCIAL VALUE AS FOOD.

October 7, 1903, Dr. A. Hrdlicka, of the U. S. National Museum, submitted for examination a large package of insects which he stated were used as fish food in Mexico, whence they came. These insects were all of the family Corixidæ, or "water boatmen," and similar to species which are found in boreal America. We also received information that they were on sale in a well-known bird store in the city of Washington. The species were three in number, and were identified by Mr. Otto Heidemann, of this Office, as *Notonecta americana* Fab., *Corixa mercenaria* Say, and *C. edulis* Champ., all of which are described in Biologia Centrali-Americana, Hemiptera-Heteroptera, Vol. II, by G. C. Champion. Writing of *mercenaria*, Mr. Champion states that it swarms in the large lakes near the City of Mexico, and much has been written about it from the economic point of view, the eggs, larvæ, and adults being collected and sold in Mexico as articles of food, it is said, for both man and birds, while of late years they were even being imported into England as food for caged birds. The food value of these insects appears to have been recognized since 1625, by Thomas Gage who is credited with being the first English traveler in Mexico. His observations have been confirmed by Say and Guèrin, the latter stating that *C. femorata* is sold for the same purpose. Immense numbers of these "water boatmen" are sometimes captured on the wing toward evening. Probably all of the "water boatmen," of which there are many species in North as well as Central America, could be utilized for the same purpose, it being merely a question of capturing them in sufficient numbers to make it profitable.

The same month Mr. George L. Hopper, of the Bureau of Fisheries, Crockett Depot, Va., furnished samples of Mexican aquatic bugs of the same species above mentioned, including two other forms, one doubtfully identified as *inscripta*. Mr. Hopper stated that the material sent for examination had just been received in several pounds in the dried state for experiment as food for young trout. The trout were eating them and doing well, and our correspondent was convinced that it was the best artificial food that had ever been used. He stated that the bugs were gathered in large quantities from Mexican lakes, especially Lakes Choleo and Texcoco. Their eggs are glutinous and adhesive to submerged objects in the same manner as is oyster spat. He adds that *Corixa femorata* is used in Mexico for the same purpose, and has long served as an article of food for the natives of Mexico.

Concerning the manner of use of these insects as fish food, Mr. Hopper stated that as they were dry they were run through a coffee mill and ground as finely as desired, after which scalding water was poured over them to soften them. They were then mixed with 20 per cent of mush, and this he stated made the best food for small fish which he had ever seen tried, and he has had many years of experience in this line of work. Thus prepared he stated the cost was about 5 cents a pound.

A NEW ENEMY OF THE PEAR.

Dr. N. Cholodkovsky, of St. Petersburg, Russia, reports in the Zoologischer Anzeiger (Vol. XXVII, pp. 118-119, 1903) the discovery of a new species of Phylloxera, infesting the fruit of several valuable varieties of pears, and to which he gives the name of *Phylloxera piri*. He states that about the middle of September colonies of small and apterous, yellowish-green lice were discovered in small depressions around the stem of numbers of pears, covered with paper bags as a protection against *Carpocapsa pomonella*, at Aluschta, Crimea, Russia; that the infested parts eventually rotted, producing irregular blackish-brown spots on the surface surrounding the stem, and that the lice had apparently lived on the pears for about a month, during which time the young or larvæ spread from one fruit to others.

Thus far this species appears to be indigenous and confined to the south of Russia, and as far as recorded is the only one of this group of plant lice discovered as infesting fruit trees.

The discovery of this new pest on the pear indicates anew the great danger of indiscriminate importations of fruit, cuttings, or growing plants from foreign countries without an adequate supervision and fumigation before shipment and thorough inspection of such a cargo prior to distribution in this country.—TH. P.

INJURY BY A CRICKET IN THE SOUTH.

During the November 11 (1903) meeting of the Entomological Society of Washington the following notes were presented by Mr. A. N. Caudell, the first portion being a letter received several years ago and the latter a report on the specimens by Mr. Caudell.

Mr. Dempsey's letter is as follows:

JENA, CATAHOULA PARISH, LA., *May 7, 1887*.

As you requested February 21 last, I send you samples of the destructive locusts which are so numerous in this parish. They infest portions of the hills and swamp lands alike, doing irreparable damage to cotton, sweet and common potatoes, peas, and tobacco. They will not reach you alive, as they die in about twenty-four hours in confinement.

Our farmers are seriously alarmed at their fearful increase and their destructive habits. Their holes in the ground are promiscuously scattered from a few inches to several feet apart, and seldom over a foot deep in the uplands, but they go much deeper in the swamp, as the soil is deeper and the subsoil softer. They are seldom visible in the heat of the day, and do their cutting at night, taking all they want down in the ground, where they eat as they please or feed their young ones. They never infest trees or injure orchards, but if they become much more numerous they may eat everything green.

In 1852 I first noticed them eating young cotton only, and a few years back they began to eat sweet potatoes; now they eat peas and tobacco, and have attacked our gardens. Our parish is composed of small farmers, who lack the means and the knowledge of how to exterminate them, and I fear that for want of discipline, unity of action, or any system of organization that the most profound scientist would fail to effect a radical cure. Were the evil only ameliorated it might save thousands of dollars and an immense amount of labor, which is worse than wasted by its disheartening nature. * * *

They appear to go in colonies, eating one man's crop while his neighbor's across the fence is not injured.

We find that rapid cultivation, large "gangs" of poultry, and numerous birds keep them in check; but they are becoming too numerous in spite of all we can do.

MICHAEL DEMPSEY.

NOTE.—This insect of economic importance has existed for many years in the United States without being, so far as I know, mentioned specifically by any writer. It is a species of the gryllid genus Anurogryllus, which I have determined as *A. antillarum* Sauss. When mature it is readily separable from its ally, *A. muticus*, by being apterous and having the elytra more abbreviated. Specimens of what I take to be the young have very small wing pads, but they are rarely discernible in the adult. The National Museum contains specimens from Florida, Alabama, South Carolina, Louisiana, and Virginia, where it is injurious to various garden crops, strawberries, peas, sweet and Irish potatoes, tobacco, and cotton.

This species probably occurs not uncommonly in collections, but has never been recorded from the United States. Mr. Rehn tells me it is present in the collection of the Academy of Natural Science of Philadelphia as *Miogryllus saussurei;* but members of that genus have fully developed ovipositors, while Anurogryllus is peculiar in having that organ aborted.—A. N. CAUDELL.

IDENTITY OF A TINGITID FOUND ON CHRYSANTHEMUM.

In Bulletin No. 10 new series (page 99), under the head of Extracts from Correspondence, a short note was published in regard to infestation of chrysanthemum leaves by a little tingitid bug received in June, 1897, from Alabama, the species having been identified at that time as *Corythuca irrorata* Riley. Dr. E. P. Felt has recently brought up the subject of the specific identity of this chrysanthemum pest, and Mr. Otto Heidemann, of this office, has furnished the following notes, which will be of value to the systematic worker.

Under date of June 11, 1903, Dr. Felt sent specimens of the same species, stating that it is seriously injuring chrysanthemum for the past year or two at Coeymans, N. Y. According to Mr. Heidemann the insect in both cases is *Corythuca marmorata* Uhl., described in Proceedings of the Boston Society of Natural History (Vol. XIX, p. 415, 1878), there being nearly perfect agreement of the specimens with the description. The type of this species is in the Harris collection now in the Boston Society of Natural History museum, No. 61, labeled in the handwriting of Uhler as *C. marmorata*.

Corythuca irrorata is a MS. name of the late Prof. C. V. Riley. It has therefore never been described, and as it is exactly like Uhler's *marmorata*, would be a synonym in any case.

CARBON BISULPHID FOR RED ANTS AND WHITE GRUBS.

Mr. Harry B. Williams, 212 Summer street, Boston, Mass., writes in regard to the efficiency of carbon bisulphid as a remedy for red ants and white grubs, both of which insects were troublesome on his lawn, that having tried hot water, kerosene, red pepper, and a few other such remedies, he wrote to this Department for information, receiving Circular 34 and Farmers' Bulletin 145. In applying the remedies, he made holes about 4 inches deep in the lawn, 2 feet apart, inserted a small funnel, and poured a small quantity, about a tablespoonful, immediately into the funnel, pulling it out and covering the hole with moist dirt. He noticed that if the bisulphid touched the grass it shriveled it at once; and if too large a dose was used, it had a tendency to kill the grass, making brown spots appear. He described the treatment as having produced very good results, having cleaned the lawn of both white grubs and red ants.

This is the standard remedy for ants in lawns, and has frequently been advised for white grubs, but the expense of using it is such that it can not always be profitably employed in large fields, though it will answer very well for lawns, and for some gardens.

AGONODERUS PALLIPES A PERMANENT ENEMY OF SPROUTING CORN.

During the latter days of July, 1903, Mr. B. D. Wilson, Hetty, Tex., sent numerous specimens of the common little carabid ground beetle, *Agonoderus pallipes*, together with samples of sprouting corn which they had injured. He reported that there seemed to be twenty of these beetles to a single grain of corn. Out of 50 acres of June corn planted he felt satisfied that he would not obtain more than 5 acres on account of the ravages of this little pest. It is now a matter of upward of twenty years since this species has attracted attention by attacking the kernels of corn in Illinois. (See Forbes's 12th Report St. Ent. Ill., p. 27.) In 1885 we received reports from Illinois and from Iowa that this species was damaging young corn by gnawing into the seed corn and eating the sprouting roots. Damage was said to be quite extensive (see Bul. No. 12, Div. Ent., o. s., p. 45).

ANTHRENUS DESTROYING TUSSOCK MOTH EGGS.

In Technical Series, No. 5, we described a newly discovered habit of the larva of *Anthrenus verbasci* (*varius*) in feeding upon the living eggs of *Hemerocampa* (*Orgyia*) *leucostigma*. Since that time this observation has not been duplicated. In October, however, Mr. D. C. Clark stated that he had noticed the same habit in Baltimore, and that he is confident that it has been during the past season of so common occurrence as to account for the scarcity of the tussock moth caterpillars upon Baltimore shade trees. Last year, in 1902, this species was about as prevalent as usual. The egg masses were about as abundant in 1903 as in 1902, but upon examination Mr. Clark could find comparatively few which had not been eaten. He found the larvæ of Anthrenus and the cast larval skins in nearly every egg mass examined. In fact, we may say, he could not find a single perfect egg mass to experiment with as to the time of hatching. This observation is of very great interest and importance. Down to the time of our note, above cited, this Anthrenus had not been known to feed upon living animal matter. Are its habits changing?

ABUNDANCE OF THE RHINOCEROS BEETLE IN SOUTH CAROLINA.

In a letter dated July 27, 1903, Hon. Wyatt Aiken, writing from Abbeville, S. C., stated that the rhinoceros beetle (*Dynastes tityus* Linn.) had attacked swamp ash grown as shade trees in that vicinity, and that the odor proceeding from the beetles, which is well known to collectors of insects from its strength and persistence, was very obnoxious. As a remedy, 80 trees were cut down by order of the town council, with the result that the offensive odor disappeared. The explanation is that the insects are more attracted to ash than to other trees, and with the disappearance of their favorite host plants in that vicinity they went elsewhere. Notes on this species, together with illustrations, were published in Bulletin 38 (on pp. 28–32).

In commenting upon the occurrence of this insect the Abbeville (S. C.) Medium of July 30, 1903, states in an editorial that several years previously similar complaints were made at Magazine Hill, which was the particular locality where the insect was a nuisance, and that the city council had destroyed trees at Fort Pickens where the insects had been noticed, as also in other parts of the city. The trees were estimated to be worth $100 each, and the loss was therefore stated to be $8,000.

THE LENGTH OF THE FIBER IN THE COCOON OF THE DOMESTIC SILKWORM.

Authorities and popular works differ greatly in their estimates of the length of the fiber in the cocoon of the domestic silkworm, *Bombyx mori*. Published statements of the length of this fiber could be cited which range all the way from 1,100 feet to 11 miles. Even so good an authority as the Encyclopædia Britannica places it at 300 yards. Recent measurements made in the Division of Entomology show that with certain Milanese yellow cocoons raised in the United States from eggs purchased from France the fiber varies in length from 888 to 1,195 yards.

EFFECT OF THE BITE OF A MIDGE ON A HUMAN BEING.

It is well known that the genus Ceratopogon, of the dipterous family Chironomidæ, or what are termed biting flies, of which the most conspicuous form is the so-called punky of the north woods of Maine, sometimes called by the Indians "No-see-'em." It is somewhat seldom, however, that the species caught in the act of biting can be determined specifically. Mr. F. W. Thurow, Harvester, Tex., sends specimens of *Ceratopogon stellifer* Coq., with report that it is very common in that vicinity (Waller County), and that a great many people have felt its bite. It is sometimes called sand gnat or sand fly, but all agree that it is very tormenting, and that it is worse near creeks that are choked with logs than elsewhere. When our correspondent first went to live in Texas he would pull off his shoes at night and sit down to read. After a while his feet and hands were burning as if he had been wading in nettles. For a long time he was of the opinion that the trouble was nettle rash, on account of the minute size of these little midges, which is well expressed by the Indian name "No-see-'em." The bite of the flies appear to be more intense about the wrists and ankles.

THE QUAIL AS A DESTROYER OF CUTWORMS.

November 14, 1902, Mr. W. F. Wever, Commerce, Tex., wrote in regard to the effectiveness of the quail in restraining the multiplication of insects, more particularly cutworms:

> My grandfather had a low piece of bottom land that cutworms were always very bad in; and upon one occasion I shot a quail in the edge of this piece of land. When the negro woman went to dress the bird, its crop was so full that she cut it open, and found 17 cutworms in it. That stopped the killing of quail, so far as my grandfather's place was concerned. I am satisfied that your Department could do some splendid missionary work along this line.

We frequently receive similar communications testifying to the value of the quail as an insect destroyer, more particularly as a check on the increase of the Colorado potato beetle (see Insect Life, Vol. IV, p. 278, and Vol. V, p. 143). Within a radius of only a few miles of the Capitol, quails are quite common during the summer months, and come very close to cottages along the Potomac River front, and may be seen crossing roads ahead of carriages almost as freely as barnyard fowls; and it seems too bad that a bird which has a tendency to frequent the vicinity of farmhouses and fields of grain and other crops where it would aid in the control of insect pests should be destroyed by alleged sportsmen as soon as the open season begins.

TOBACCO FOR THOUSAND-LEGGED WORMS.

A writer in the Weekly Florists' Review of April 9, 1903, Mr. William Scott, states, in answer to a correspondent of that publication who requested a remedy for thousand-legged worms or millipedes working on his ferns and which he stated were eating some of his asparagus seed, that thousands of these creatures appeared on the surface of rose beds, but that after putting bunches of tobacco stems on the surface to keep down "green fly" or aphides, it was noticed that the "thousand legs" lay around dead, and their demise could be attributed to nothing but the tobacco. Mr. Scott therefore advises that in order to rid greenhouses of "thousand legs" to put plenty of fresh tobacco stems among the pots.

LIGHTS AGAINST THE IMPORTED CABBAGE WEBWORM.

Mr. H. M. Simons, who appears to be the first person who has had experience with *Hellula undalis* in this country, wrote from Charleston, S. C., August 11, 1902, that he captures many of the moths with the aid of a barrel having all but four of the staves sawed out, leaving 4 inches from the bottom to form a tub in which to hold water. From the top of this a light is suspended which attracts the moths. The light barrels, as he terms them, were placed on plant seed beds of cabbage.

A thin scum of kerosene was used in this experiment, but it is suggested that this be eliminated, in order not to destroy predaceous insects, such as ground beetles, which are almost sure to be attracted; this suggestion being made in view of the fact that the destruction of one individual of a beneficial species is equivalent to the destruction of perhaps 20 to 100 injurious ones. The useful insects can be easily picked from the water, and though they may apparently be dead, they usually recover and crawl away.

HAIR WORMS IN CABBAGE.

Many complaints have been made during the present year of what have been termed by various persons as "snakes," "cabbage snakes," "snake worms," and the like, and the subject has attained considerable newspaper notoriety. So many inquiries have been made as to the identity of the creatures and their alleged poisonous qualities that it has been thought well to give a short account of them, more particularly as many persons fully believe the insects to be poisonous. This is, of course, absurd, as the worms are not known to possess any toxic properties whatever, but it is certain that, although they are not injurious to the cabbages their presence is not desirable, as they really injure cabbage for sale. The specimens received during the year, with a few exceptions, have been found in heads of cabbage. We have ascertained from Dr. C. W. Stiles, consulting zoologist in charge, Bureau of Animal Industry of this Department, that the species is *Mermis albicans*, Diesing,[a] in each case represented by the female. The creature is not an insect nor a snake, but one of the hair worms of the family Gordiidæ. It has been well described by one of our correspondents as a white worm, looking like a piece of basting thread. It is usually found coiled or crawling about in the cabbage in which it is found. Its length when full grown is about 3 inches. This little hair worm has been reported in cabbage, with the usual account of its being injurious and poisonous, from Glades, Clayton, Ga.; Earleyville, Tracy City, Tennile Stand, and Greenville, Tenn.; Chester and Tucapau, S. C.; Shreveport, La., and several other localities from which no specimens were received.

It is usually stated to be found in the solid part of the head of cabbage between the leaves. One correspondent says that it is a serpent, a vicious little reptile; others that it develops in stagnant water and transforms from horsehair, a very prevalent opinion among many people. A statistical correspondent of this Department makes mention of some current reports in a portion of Tennessee to the effect that a number of people had died from eating cabbage affected by this creature, while others were made very sick. A physician reported that when cabbage infected by the hair worms was eaten that it produced instant death. In one newspaper report this hair worm is stated to have been examined by the State chemist, and found to contain enough poison in it "to kill eight persons." Another newspaper notice is to the effect that it has seriously injured the demand for cabbage in a number of Georgia cities, causing in the aggregate considerable loss to truckers and farmers. The "snake" was said to have no vertebræ, but it would strike "just as if it were a member of the snake family," and tons of good cabbage were being thrown away on account of its presence. In this case it was light red in color and 4 inches long. Crowds assembled to examine specimens and "snakes" was the principal topic of conversation even after one had traveled a mile or two up on the mountain side.

This same species was received in a piece of apple which was apparently sound. It was found coiled inside near the seed. A related species is known to be parasitic upon the codling moth or "apple worm" (*Carpocapsa pomonella*), and there is no doubt that the present species has the same habit, from its occurrence, as described.

One other hair worm (*Paragordius varius*) was sent, found in the water without visible means of support in Virginia.

A very large proportion of the hair worms are parasitic on insects.

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[a] From the studies of Diesing, Meissner, and others, it has been concluded that *M. albicans* is merely the mature sexual form of *acuminata*, but the latter name seems to have priority

The species of Gordius and Mermis are treated somewhat at length in the first report of the U. S. Entomological Commission, published in 1877, pp. 326–334. Among the hosts of hair worms in which they are most frequently found are aquatic insects, also insects of the order Orthoptera, which includes grasshoppers or locusts, crickets, and katydids. They are also sometimes parasitic on beetles, more particularly Carabidæ or ground beetles, bees and flies, and caterpillars of butterflies and moths, and even on snails. Among other sensational reports received were those of what was described as an insect of a brown color which had similar habits and poisonous properties to the cabbage snakes. Only two correspondents responded with specimens when requested. These were referred to Mr. O. F. Cook, who stated that they belonged to the genus Geophilus, which includes several species of myriopods or thousand-legged worms, all of carnivorous habits, and it is possible that they may attack some of the smaller forms of cabbage worms and hence be beneficial.

It should scarcely be necessary to add that inasmuch as the first reports that were received, including the bulk of the newspaper accounts, were of such a nature that it was impossible to identify the creature concerned other than to surmise that it was a species of Mermis, and in reply to inquiry to give what was known of the habits of the genus. It was, therefore, a matter of considerable perplexity to know if this surmise was really correct, and it was also a matter that gave considerable annoyance to many of the State entomologists and chemists of the Southern States where the Mermis abounded.

OBSERVATIONS ON THE HABITS OF THE MORNING-GLORY LEAF-CUTTER.

(*Loxostege obliteralis* Walk.)

During the latter days of August and the first half of September, 1903, this species was very evident on several kinds of ornamental plants growing in yards in the city of Washington. Although morning-glory is the preferred food, when the larva has fully matured it frequently leaves this plant and cuts the leaves of plants on which it does not feed to form its characteristic pupal case, which has already been mentioned and figured in Bulletin 27, new series (p. 104). In spite of its bright colors, the insect appears to prefer very shady locations, and this is fortunate, as it is seldom found in well-kept front yards, but in back yards near high board fences and in places where morning-glory and some other plants of volunteer growth riot over fences, sheds, and outhouses. Here, where the leaf-cutter is well protected from the sun, it develops in great numbers. Indications are that the larvæ usually pass all of their earlier stages on morning-glory, and that it is only in the last stage that they ordinarily forsake this plant for others, but in the event of the scarcity of morning-glory they could probably develop on various other plants without strong odor. Geraniums have never been found to be eaten, but they seem rather to prefer this plant to cut off for forming pupal cases when they can obtain it. Larvæ were noticed, although sparingly, feeding on violet, Commelina, and plantain, and more commonly on zinnia.—F. H. C.

NEW HABITS OF THE CUCUMBER FLEA-BEETLE.

(*Epitrix cucumeris* Harr.)

Beginning with the first week of June, 1903, the writer noticed general infestation of ornamental petunias by flea-beetles, evidenced by characteristic small punctures in the leaves. The depredator proved to be *Epitrix cucumeris*, and the cause for injury was also evident, as the insect was found developing on *Solanum nigrum* growing as a weed in the flower beds. A few wild plants remaining here and there were overlooked by the gardener. The destruction of the weeds caused the insects to migrate to the petunias. It was also noticed that this species occasionally attacked wild Acalypha, but not the cultivated plant of the same genus.

August 11, 1903, Mr. A. D. Shamel, Tariffville, Conn., reported this species to be doing great damage to tobacco, confining itself to Cuban tobacco, and that it attacked the leaves just before picking. Nothing like it had been seen before, which is doubtless to be accounted for by the fact that tobacco has not been raised on a large scale for many years in Connecticut. There is danger of this species replacing *Epitrix parvula* as a tobacco pest, the brown species doing the greatest injury in the South, the black one northward.—F. H. C.

ON REMEDIES FOR GARDEN SNAILS.

The year of 1903 was remarkable for the numerous complaints made of snails and their injuries to ornamental and vegetable garden and similar plants. From the District of Columbia and westward to Minnesota, as well as in the more southern regions, these creatures did considerable damage, their work closely resembling that of caterpillars. One of our correspondents, Mr. Phares R. Nissley, Landisville, Lancaster County, Pa., wrote under date of February 29, in answer to a letter in which we requested his experience in the use of the remedies advised, that he had used air-slaked lime and salt, and a mixture of salt and lime, and both were effective, but that lime was the best remedy, and when even a small particle was dropped on a snail it would die in fifteen minutes. These remedies were practicable when plants had got well started, but trouble came when tobacco and celery seed were sowed. As soon as they were well sprouted the snails devoured them, and it was impossible to sprinkle the lime on the plants at this time, showing that the lime is effective practically only on plants that are of sufficient growth to be dusted. We have also advised our correspondent o use soot and fine road dust, and it seems possible that if these ,en spoiled flour were mixed with lime and carefully sifted ar ' ..en gently puffed on the plants by means of an ordinary powder atomizer, of 4 or 5 inches diameter, and costing about 15 to 25 cents, this would destroy or deter the snails from injuring the plants. Salt is also a good remedy for slugs. The reason for the great injury by snails was doubtless due to the unusually cool and very damp weather experienced over a large portion of the country.

EXTRACTS FROM CORRESPONDENCE

Supposed Cutworm Injury to Orange Fruit.—During August, 1903, we received two communications from correspondents in Florida, one from Dr. Leon A. Peek, of Melbourne, with accompanying specimens of oranges which had dropped from the trees, and which showed what seemed to be the work of climbing cutworms possibly, but the pest itself could not be discovered. One of our correspondents was of the impression that the Mexican or Morelos orange worm was at work. From Mr. G. H. Carr, of Hypoluxo, Fla., we received a similar complaint. In neither case was the correspondent able to locate the culprit. In the first instance of injury the orange sent was a "drop." Our second correspondent believed that the oranges were injured while on the trees.

By using a curculio catcher or large inverted umbrella under the branches and jarring them lightly, the insect should be dislodged, particularly if this method of capturing them were employed at night with the aid of a lantern.

Cotton Bands about Trees for Cutworms.—A correspondent in California wrote this Office in 1903 that he had protected his young walnut trees, 400 in number, by wrapping the trunks with cotton saturated with crude petroleum. This grower may consider himself fortunate if he does not lose all his trees.

Remedy for Cabbage Worms and Plant-Lice.—Edward S. Thomas, Marshfield Hills, Mass., wrote, under date of September 21, 1903, that he had used very successfully a compound called "Fly Killer" (to be used on cows and horses) as a spray to kill the green cabbage worm and plant-lice. It killed instantly and has not harmed the cabbage, so he writes.

The Bollworm Moth at a High Elevation.—We received word from Prof. T. D. A. Cockerell, May 4, 1903, that the previous day he observed at Placita, N. Mex., about 6,850 feet above sea level, specimens of the bollworm moth (*Heliothis armiger*) busily sucking the flowers of wild plum. One of the specimens was unusually reddish.

A Cabinet Beetle in a Locket.—Dr. George S. Yingling, Tiffin, Ohio, sent to this Office, with accompanying letter dated May 30, 1903, a glass charm with sterling silver band, inclosing a common French beetle, frequently used as an ornament, together with larva of the cabinet beetle (*Trogoderma tarsale*) which was destroying it. By careful examination of the top of the charm it was seen that there was a crack large enough for the admission of the larva while it was young.

Food Habits of a Tree Cricket.—Mr. Alva A. Eaton, of Seabrook, N. H., has made some interesting observations on the food habits of (*Ecanthus quadripunctata* Beutenmüller, in which, by careful experimentation, he proved that a half-grown specimen of this tree cricket destroyed plant-lice, devouring a full-grown louse in about ten minutes. The forelegs were used to hold the plant-louse, which was devoured, legs and all. While feeding, the antennæ of the cricket were held erect, and while searching for lice they were held horizontal. A single individual was seen to destroy nearly forty plant-lice.

A Food of Robber-Fly Larvæ.—The Mr. Eaton referred to in the last note, has found the larvæ of a robber fly feeding upon white grubs (larvæ of Lachnosterna).

A Tachina Parasite of May Beetles.—Mr. Eaton has also found the puparium of a Tachina fly beneath the empty carapace of a May beetle (*Lachnosterna* sp.) which it had evidently destroyed before it issued from the ground. Tachina eggs have been found by the writer attached to the thorax of Lachnosterna, but no better proof of this parasitism is upon record.

Strange Habits of a Tropical Cricket in South Carolina.—May 14, 1903, Mr. Harry Hammond, Beech Island, S. C., sent specimens of a cricket, *Anurogryllus muticus* DeGeer, with accompanying information that the insects make holes in cotton fields to the depth of 18 inches, which they line with shreds of cotton leaves, destroying the young cotton for several feet in the row in accomplishing this. Until the discovery of these crickets it was surmised that the damage was entirely due to cutworms, some species of which have the habit of dragging vegetation into holes in the ground. The young of the cricket were found in these holes in June, and the insect lives in cornfields and in fields lying fallow, as also in cotton fields. The species in question is tropical and a native of the West Indies, Central and South America. It does not appear to have been recorded as occurring in America north of Mexico, and nothing appears in regard to its habits.

Hydrocyanic-acid Gas for the Destruction of Mealy-Bugs.—Mr. John L. Chapman, Bradley Hill, Hingham, Mass., wrote November 27, 1903, that, in accordance with directions furnished in Circular No. 37, of this Office, he had killed mealy bugs on grapevines by an exposure of only two hours, the gas being used at the rate of 1 ounce to 300 cubic feet of space. The day following exposure he was unable to find a single mealy-bug on the vines or leaves of the plants exposed to the gas, but the eggs appeared to be intact, which would of course necessitate another fumigation.

Kerosene as a Remedy for the Clover Mite.—Under date of May 4, 1903, Mrs. Mary E. Burrell, Freeport, Ill., writes that kerosene has proved effective in her experience in ridding her house of the clover mite (*Bryobia pratensis*). She used it without dilution, dipping a cloth and without wringing wiping the sill and lower edge of the window sash, also leaving what adhered to the glass on rubbing it over, for an hour or more. Three applications were sufficient to rid the house of the pest.

Carnivorous Habits of *Polystœchotes punctatus* Drury.—A specimen of this species of Hemerobiidæ was sent to the Division of Entomology by Mr. Henry Talbott, of Washington, who had found it on a fishing excursion in the northern States. The specimen was still living, while the wings of three of its companions, which had been placed in a box together with it, were all that remained of them. The bodies, heads, and nearly every portion of the others had been destroyed, including even portions of the wings. The living specimen was not much damaged.

A Mite in Sugar Withstanding Severe Cold Weather.—During January, 1904, Mrs. Eva Bashaw, Mankato, Minn., sent a species of Tyroglyphus found in brown sugar and dried fruit, with report that it was able to withstand freezing. At our suggestion the matter was tested. A paper sack of sugar containing numerous individuals of the insect was left out of doors over night with the thermometer at 8° below zero. It was again put out for three days subject to about the same exposure, and when heat was applied the insects began to crawl about.

A Mushroom-Infesting Mite.—*Tyroglyphus lintneri* Osb., an account of which, with Osborn's illustrations, is given on pages 452 and 453 of Lintner's Tenth Report, was identified by Mr. Banks in connection with injury to young mushrooms picked from the beds on the morning of December 5, 1902, at Western Springs, Ill., by Julius M. Keil. They were covered with myriads of the little creatures which were devouring them, stopping their growth so that our correspondent was unable to obtain a fair crop.

A Myriopod Stated to Injure Vegetation.—Writing October 2, 1903, Mr. J. F. Schermerhorn, Alton, Ill., sent a specimen of the larger and common myriopod, *Spirobolus marginatus* Say, with statement that it had been found on a leaf of egg-plant and that when disturbed it emitted a fluid that destroyed vegetation within ten minutes. It is well known that myriopods contain a small amount of hydrocyanic acid, but we have no records of injury to vegetation at the present time by any of these insects in the manner described.

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U. S. DEPARTMENT OF AGRICULTURE,

DIVISION OF ENTOMOLOGY—BULLETIN No. 45.

L. O. HOWARD, ENTOMOLOGIST.

THE MEXICAN COTTON BOLL WEEVIL.

NSECTS

PREPARED UNDER THE DIRECTION OF THE ENTOMOLOGIST

BY

W. D. HUNTER and W. E. HINDS.

234155

WASHINGTON:
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1904.

DIVISION OF ENTOMOLOGY.

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Miss L. L. HOWENSTEIN, *artist.*

DEVELOPMENTAL STAGES AND WORK OF THE BOLL WEEVIL.

Fig. 1, Cotton boll weevil; fig. 2, weevil feigning death; fig. 3, two eggs and feeding excavation in a square; fig. 4, full-grown larva; fig. 5, pupa, ventral view; fig. 6, pupa, side view; figs. 7-9 show transformation taking place within squares: fig. 7, larva, full grown; fig. 8, pupa; fig. 9, adult; fig. 10, weevils feeding on boll; fig. 11, larva developing in boll. (Figs. 1-10, natural size; fig. 11, two-thirds natural size.—Original.)

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., February 20, 1904.

SIR: I have the honor to transmit herewith for publication an account of the Mexican cotton boll weevil, prepared under my direction by Messrs. W. D. Hunter and W. E. Hinds, special field agents of this Division. Mr. Hunter has been engaged for three years in investigations of this very important injurious insect, his work extending all through the infested portions of Texas and to some extent into Mexico. Mr. Hinds for two years has been devoting his whole time to this subject, having been stationed for the most part at Victoria, Tex., in charge of laboratory work. The bulletin as a whole is a remarkably careful and complete treatment of the entomological aspects of the investigation. It seems to me as complete a treatise of the life history of a single species as has ever been published. The necessity for the most perfect knowledge of every detail of the habits of this great enemy to the cotton crop must be obvious, since only upon such perfect knowledge can we authoritatively base remedial work and can we authoritatively indicate the uselessness of many of the remedies proposed by ingenious and inventive persons. The sixteen half-tone and other plates and six text figures are an essential part of the report.

I recommend the publication of this paper as Bulletin No. 45 of this Division.

Respectfully,

L. O. HOWARD,
Entomologist.

Hon. JAMES WILSON,
Secretary of Agriculture.

PREFACE.

The Mexican cotton boll weevil (*Anthonomus grandis* Boh.) has the unique record of developing in less than twenty years from a most obscure species to undoubtedly one of the most important economically in the world. It was first brought to the attention of the Division of Entomology as an enemy of cotton in Texas in 1894. Before it had invaded more than half a dozen counties in the extreme southern portion of Texas several entomologists were sent to the region in connection with this work. Enough was soon discovered to indicate the most feasible plans for avoiding damage by the pest. These original plans, based upon investigations of the life history of the insect, with modifications, for the most part due to climatic conditions in regions quite dissimilar to the lower portion of Texas, are still the basis for all that is known in combating the pest. However, at that time it was necessary to pay particular attention to the immediate economic phases of the problem, and a detailed study of the habits of the insect was impossible. In 1902, by the aid of a special appropriation by Congress, it became possible to establish a complete field laboratory in the portion of Texas in which the weevil had been known to exist at that time for about eight years, where a careful investigation could be conducted regarding the points in the life history of the pest that offered even remote chances of suggesting means of avoiding damage. The results of the work at this laboratory that have been of more immediate economic bearing have already been published in farmers' bulletins of this Department. However, as will be seen from the following pages, a very large mass of information concerning all the habits of the boll weevil has been accumulated. Not only on account of the great economic importance of the problem and the demand for information from numerous quarters concerning the biology of the pest, but also on account of the fact that the methods followed in this work have been to some extent original, and may be of use in connection with the investigation of other insects, it is thought advisable to publish a great number of the observations that have been made.

The historical and economic features, to which reference has been made elsewhere in the publications of the Division, are included to bring together in convenient form practically all that is known regarding the species. Much information obtained by the earlier investigators of the Division of Entomology, Dr. L. O. Howard, Mr. C. L. Marlatt, Mr. C. H. T. Townsend, and Mr. E. A. Schwarz, has been used. On account of the painstaking character of the work of Mr. Schwarz, and his intimate knowledge of related species, his reports, largely unpublished, have been found especially valuable. In presenting this work the authors have taken care to state fully the data furnishing the basis for the various conclusions. Under each important heading will be found, first, a description of the methods and apparatus employed; second, a full and in many cases tabular statement of observations; third, the obvious conclusions. Care has constantly been exercised to avoid errors likely to result from artificial conditions in the laboratory. A large part of the work of the past year was in ascertaining how closely laboratory results corresponded to the actual conditions in the field. The writers have on many occasions been surprised to discover how close the correspondence is, and consider that the demonstration on a large scale of the possibility of accurately determining the details of the life history and habits of an insect by laboratory investigations is by no means the least important of the results of the investigation.

The laboratory work which has led to this paper was planned originally by the senior author, who has also supervised the later developments of it. However, practically all the labor of conducting the experiments and observations has devolved upon the junior author, who has suggested from time to time many important modifications of the original plan. Specifically, all of the bulletin except the first portion, dealing with historical matters, the destructiveness of the pest, and the prospects, and the last portion, dealing with methods of combating it, was written by the junior author, although revised in some particulars after it had been submitted by him. The illustrations used are from photographs taken for this work by the junior author, with the exception of the text figures and the illustrations of insects often mistaken for the boll weevil, of which those marked "original" are, with one exception, from drawings prepared by Miss L. L. Howenstein, one of the artists of the Division of Entomology.

CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

THE MEXICAN COTTON BOLL WEEVIL.

GENERAL CONSIDERATIONS.

HISTORICAL.

There is very little certainty regarding the history of the Mexican cotton boll weevil before it came to the attention of the Division of Entomology in Texas in 1894. The species was described by Boheman in 1843 from specimens received from Vera Cruz, and it was recorded by Suffrian in 1871 as occurring at Cardenas and San Cristobal in Cuba. Written documents in the archives at Monclova, in the State of Coahuila, Mexico, indicate that the cultivation of cotton was practically abandoned in the vicinity of that town about the year 1848, or at least that some insect caused very great fears that it would be necessary to abandon the cultivation of cotton. A rather careful investigation of the records makes it by no means clear that the insect was the boll weevil, although there is a rather firmly embedded popular notion in Mexico, as well as in the Southern United States, that the damage must have been perpetrated by that species. As far as the accounts indicate, it might have been the bollworm (*Heliothis armiger*) or the cotton caterpillar (*Aletia argillacea*).

From the time of the note by Suffrian regarding the occurrence of the weevil in Cuba in 1871 up to 1885 there has been found no published record concerning it. In 1885, however, C. V. Riley, then Entomologist of the Department of Agriculture, published in the report of the Commissioner a very brief note to the effect that *Anthonomus grandis* had been reared in the Department from dwarfed cotton bolls sent by Dr. Edward Palmer from northern Mexico. This is the first account associating the species with damage to cotton. The material referred to was collected in the State of Coahuila, supposedly not far from the town of Monclova. The exact date at which the insect crossed the Rio Grande into Texas is as uncertain as the means whereby this was accomplished. All that can be found, which is mostly in the form of testimony of planters in the vicinity of Brownsville, indicates that the pest first made its appearance in that locality about 1892. In 1894 it had spread to half a dozen counties in the Brownsville region, and during the last months of the year was brought to the attention of the Division of Entomology as an important enemy of cotton. Mr. C. H. T. Townsend was immediately sent to the territory affected. His report was published in March, 1895. It dealt with the life history and habits of the insect, which were then completely unknown, the probable method of its importation, the damage that might result from its work, and closed with recommendations for fighting it and preventing its further advance in the cotton-producing regions of Texas. It is much to be regretted that the State of Texas did not adopt at that time the suggestion made by the Division of Entomology that a belt be established along the Rio Grande in which the cultivation of cotton should be prohibited, and thus cut off the advance of the insect.

The events of the last few years have verified the prediction of the Division of Entomology in regard to the advance made and the damage caused by the insect.

In 1895 the insect was found by the entomologists, who continued the investigation started the year before, as far north as San Antonio and as far east as Wharton. Such a serious advance toward the principal cotton-producing region of the State caused the Division to continue its investigations during practically the whole season. The results of this work were incorporated in a circular by Doctor Howard, published early in 1896, in both Spanish and English editions.

An unusual drought in the summer of 1896 prevented the maturity of the fall broods of the weevil, and consequently there was no extension of the territory affected. It should be stated in this connection that the region from San Antonio to Corpus Christi and thence to Brownsville will frequently pass through similar experiences, which will be quite different from anything that may be expected to occur in regions where the rainfall is more certain. In 1900 as well as in 1903, in all or part of the region referred to, the numbers of the weevil were reduced by climatic conditions, principally a scanty rainfall, so that they were comparatively unimportant factors. During 1896 the investigations were continued and the results published in another circular issued in February, 1897. This circular was published in Spanish and German, as well as English editions, for the benefit of the very large foreign population in southern Texas.

The season of 1897 was in many respects almost as unfavorable as that of 1896, although the pest increased its range to the region about Yoakum and Gonzales. Although this extension was small it was exceedingly important, because the richest cotton lands in the United States were beginning to be invaded. The problem had thus become so important that Mr. Townsend was stationed in Mexico, in a region supposed to be the original home of the insect, for several months to discover, if possible, any parasites or diseases that might be affecting it, with the object of introducing them to prey upon the pest in Texas. Unfortunately nothing was found that gave any hope of material assistance in the warfare against the weevil.

The season of 1898 was very favorable for the insect. Bastrop, Lee, and Burleson counties became invaded, and some isolated colonies were found across the Brazos River, in Waller and Brazos counties. Investigations by the Division of Entomology were continued, and a summary of the work, dealing especially with experiments conducted by Mr. C. L. Marlatt in the spring of 1896, was published in still another circular. At this time the legislature of the State of Texas made provision for the appointment of a State entomologist and provided a limited appropriation for an investigation of means of combating the boll weevil. In view of this fact the Division of Entomology discontinued, temporarily, the work that had been carried on by having agents in the field almost constantly for four years, and all correspondence was referred to the State entomologist; but, unfortunately, the insect continued to spread, and it soon became apparent that other States than Texas were threatened. This caused the work to be taken up anew by the Division of Entomology in 1901, in accordance with a special appropriation by Congress for an investigation independent of that being carried on by the State of Texas and with special reference to the discovery, if possible, of means of preventing the insect from spreading into adjoining States.

In accordance with this provision an agent was sent to Texas in March and remained in that State until December. He carried on cooperative work upon eight of the larger plantations in the weevil region. The result of his observations was to suggest the advisability of a considerable enlargement of the scope of the work. It had been found that simple cooperative work with the planters was exceedingly unsatisfactory. The need of a means of testing the recommendations of the Division of Entomology upon a large scale, and thereby furnishing actual demonstrations to the planters, became apparent. Consequently, at the suggestion of the Department of Agriculture, provision for an enlargement of the work was made by Congress. Agreements were entered into with two large planters in typical situations for testing the principal features of the cultural system of controlling the pest upon a large scale. In this way 125 acres at Victoria and 200 acres at Calvert were employed. At the same time the headquarters and laboratory of the special investigation were established at Victoria, and such matters as parasites, the possibility of poisoning the pest or of destroying it by the use of machines, as well as investigating many of the features of its biology that were still absolutely unknown, were given careful attention by a specially trained assistant whose services were procured for that purpose. The results of the field work for this year were published in the form of a Farmers' Bulletin entitled "Methods of Controlling the Boll Weevil; Advice Based on the Work of 1902;" but on account of the late date of the establishment of the laboratory (June), and the consequent incompleteness of many of the records, it was not thought advisable to publish anything concerning the laboratory investigations. During this season cooperation was carried on with the Mexican commission charged with the investigation of the boll weevil in that country, which was arranged on the occasion of a personal visit of Dr. L. O. Howard to the City of Mexico in the fall of 1901. Specimens of parasites were frequently exchanged, and through the courtesy of Prof. A. L. Herrera, chief of the Mexican commission, an agent in charge of the investigation in Texas visited the laboratories at the City of Mexico and Cuernevaca, where a study was made of the methods of propagating parasites, especially *Pediculoides ventricosus* Newp. A large number of specimens of this mite was brought back to Texas, where they were carried through the winter successfully and used in field experiments the following season.

The favorable reception by the planters of Texas of the experimental field work conducted during this season, with the increased territory invaded by the pest, brought about an enlarged appropriation for the work of 1903. By enactment which became effective on the 4th of March $30,000 was placed at the disposal of the Division of Entomology. It thus became possible to increase the number and size of our experimental fields as well as to devote more attention to the investigation of matters suggested by previous work in the laboratory. Seven experimental farms, aggregating 558 acres, were accordingly established in as many distinct cotton districts in Texas. Despite generally very unfavorable conditions the results of this experimental work demonstrated many important points. The principal ones are detailed in Farmers' Bulletin No. 189 of this Department.

DESTRUCTIVENESS.

Various estimates of the loss occasioned to cotton planters by the boll weevil have been made. In the nature of the case such estimates must be made upon data that is difficult to obtain and in the collection of which errors must inevitably occur. There is, of course, a general tendency to exaggerate agricultural losses, as well as to attribute to a single factor damage that is the result of a combination of many influences. Before the advent of the boll weevil into Texas unfavorable weather at planting time, summer droughts, and heavy fall rains caused very light crops to be produced. Now, however, the tendency is everywhere to attribute all of the shortage to the weevil. Nevertheless, the pest is undoubtedly the most serious menace that the cotton planters of the South have ever been compelled to face, if not, indeed, the most serious danger that ever threatened any agricultural industry. It was generally considered, until the appearance of the pest in Texas, that there were no apparent difficulties to prevent an increase in cotton production that would keep up to the enlarging demand of the world until at least twice the present normal crop of about 10,500,000 bales should be produced. Now, however, in the opinion of most authorities, the weevil has made this possibility very doubtful, although the first fears entertained in many localities that the cultivation of cotton would have to be abandoned have generally been given up. An especially unfavorable feature of the problem is in the fact that the weevil reached Texas at what would have been, from other considerations, the most critical time in the history of the production of the staple in the State. The natural fertility of the cotton lands had been so great that planters had neglected completely such matters as seed selection, varieties, fertilizers, and rotation, that must eventually receive consideration in any cotton-producing country. In general, the only seed used was from the crop of the preceding year, unselected and of absolutely unknown variety, and the use of fertilizers had not been practiced at all. Although it is by no means true that the fertility of the soil had been exhausted, nevertheless, on many of the older plantations in Texas the continuous planting of cotton with a run-down condition of the seed combined to make a change necessary in order to continue the industry profitably.

A careful examination of the statistics, to which more complete reference is made in Farmers' Bulletin No. 189, has indicated that the pest causes a reduction in production for a few years after its advent of about 50 per cent, but at the same time it is evident that most planters within a few years are able to adopt the changes in the system of cultivating this staple that are made necessary by the weevil, so that the damage after a short time does not compare with that at the beginning. Upon the foregoing basis, during the season of 1903 the weevil caused Texas cotton planters a loss of about $15,000,000, and this estimate agrees rather well with estimates made in other ways by the more conservative cotton statisticians. A similar estimate made in 1902 led to the conclusion that the damage amounted to about $10,000,000. It consequently appears that during the years the pest has been in Texas the aggregate damage would reach at least $50,000,000. Many conditions of climate and plantation practice in the eastern portion of the cotton belt indicate that the weevil problem will eventually be as serious east of the Mississippi as it now is in Texas. According to the estimates of Mr. Richard H. Edmunds, the editor of Manufacturers' Record, the normal cotton crop of the United States represents a value of $500,000,000, the extreme ultimate damage that the pest might accomplish over the entire belt would be in the neighborhood of $250,000,000 annually, provided none of the means of avoiding damage that are now coming into common use in Texas were adopted. In spite of the general serious outlook, however, it must be stated that fears of the damage the weevil may do are very often much exaggerated, especially in newly invaded regions. It is not at all necessary to abandon cotton. The work of the Division of Entomology for several seasons has demonstrated that a crop can be grown profitably in spite of the boll weevil, and this experience is duplicated by many planters in Texas.

TERRITORY AFFECTED.

At the present time the boll weevil has not been found in the United States outside of Texas (see fig. 1) except in three instances in Louisiana. In one of these cases, at the sugar experiment station at Audubon Park, in the vicinity of New Orleans, the circumstances have led the State authorities to the conclusion that the pests were purposely placed in the fields. The other two cases are isolated occurrences in Sabine Parish, in the extreme western part of the State. Both of these are apparently traceable to importation from the opposite county in Texas, in cotton seed used for planting purposes or possibly in hay. The authorities totally destroyed the cotton growing at the experiment station at Audubon Park, La., as soon as the presence of the weevils was discovered. As no cotton is grown within 9 miles of that point, it seems altogether likely that the colony may have been completely exterminated. Similar action is being taken regarding the two colonies found in Sabine Parish.

In Texas the infested area extends from Brownsville, where the weevil originally entered the State, to Sherman. Shelby and Morris counties represent the extreme eastern range. The cotton acreage involved in this territory includes about 30 per cent of the cotton acreage of the United States, which produced in 1900 about 35 per cent of the total crop of this country, or about one-fourth of the crop of the world for that year. There is, however, a considerable belt between about the latitude of Dallas and the Red River where the pest does not occur in uniform numbers in all cotton fields, and consequently the general damage has not been great. It may be a matter of only two or three years before it will become sufficiently numerous to cut down the total production.

There are some features of special interest in the situation in Cuba. Although the weevil has long been known to occur in the island, it has attracted very little attention on account of the fact that the cultivation of cotton was abandoned for a long time in favor of crops that have been more profitable. Now, however, with the better price of the staple and rather unsatisfactory returns from some other crops, cotton is being planted upon a considerable scale. Mr. E. A. Schwarz was sent to the island on two occasions to study the conditions there. Although his report refers especially to the Province of Santa Clara, it is probably true that conditions similar to those he describes obtain everywhere. He found that the entire province is naturally more or less infested by the boll weevil, and that weevils did not spread from cultivated cotton planted with seed obtained in the United States to the wild plants, as at first supposed, but from the latter to the former. The weevils were found to be more numerous on the kidney cotton growing wild than on the loose cotton (seminiella). The latter, when growing alone, was usually found to be free from weevils, but liable to be infested when growing in the vicinity of kidney cotton. A large

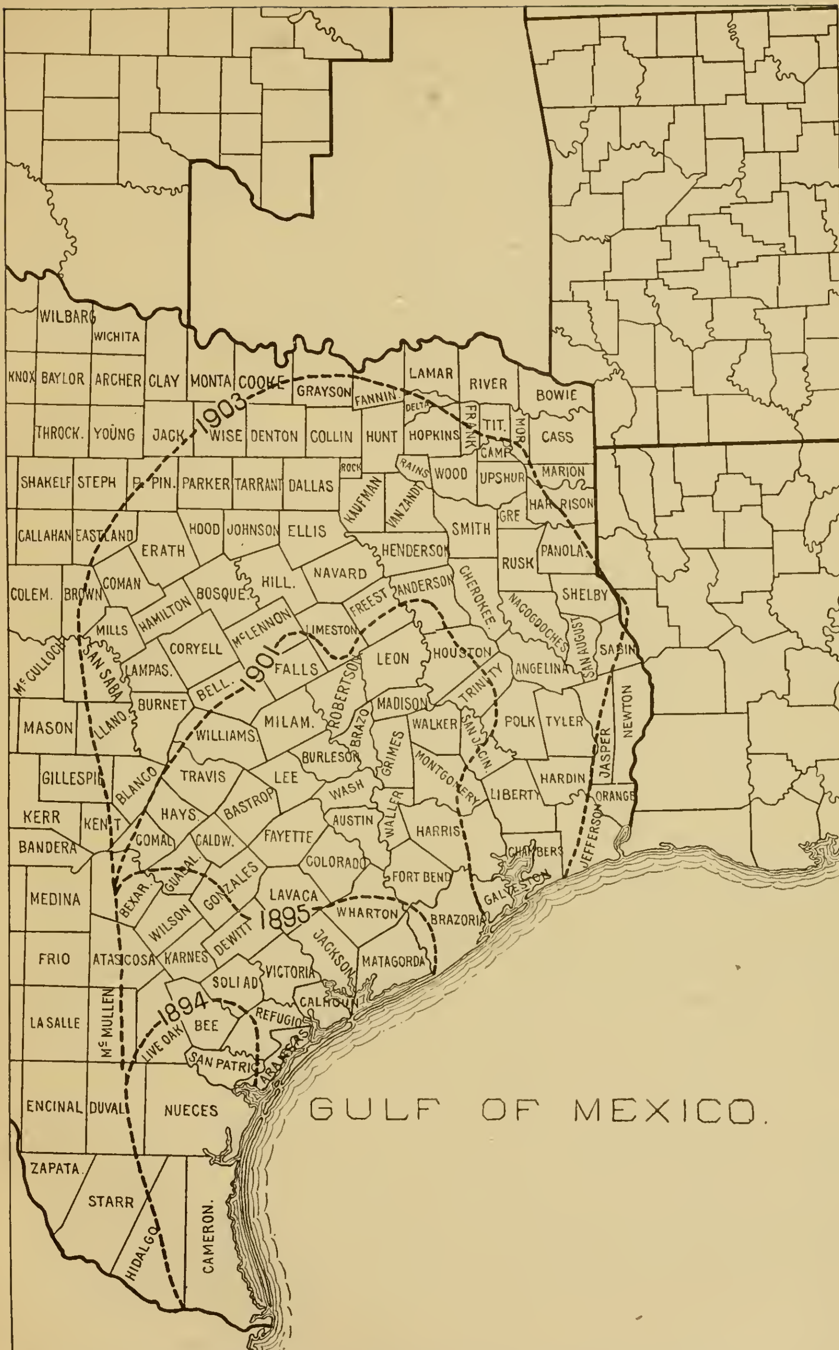


FIG. 1.—Map showing area infested by Mexican cotton boll weevil (redrawn.)

number of wild cotton trees growing in the vicinity of dwellings or growing entirely wild are always infested, and here the weevils are more numerous, but never as numerous as on the cultivated Egyptian cotton. At one locality, where a large number of kidney cotton trees were growing (about 50 plants, some of them probably 20 years old), it was found that at least one out of every twenty squares had been punctured by the first week in March. From Mr. Schwarz's report it does not seem that there is a very promising outlook for cotton raising in Cuba. The presence of wild perennial cotton, upon which the weevil probably exists everywhere, will always be a source of danger. The long moist seasons and mild winters will form more favorable conditions for the pest than will occur anywhere in the United States.

PROSPECTS.

The investigations of the life history of the weevil that are referred to in detail in the following pages have indicated that the most important elements in limiting the spread of an insect—namely, winter temperatures and parasites—in this case offer no assurance that the pest will soon be checked. For the past ten years, except where local unfavorable conditions have interfered, it has advanced annually a distance of about 50 miles. The insect is undoubtedly changing its habits and adapting itself to climatic conditions in new regions that it is invading. It is undoubtedly true that it has acquired an ability to withstand more severe frosts than occurred in the vicinity of San Antonio in 1895. Except in a few particular regions, however, it does not seem that the continued spread will be as rapid as it has been. The country between Gonzales County and the Red River is practically a continuous cotton field, and the prevailing winds have undoubtedly favored the northward spread of the insect. Similar conditions will now favor a rapid extension into the Red River valley in Louisiana, and likewise there seems no doubt that the spread will be rapid in the Yazoo valley in Mississippi; but in most other situations throughout the belt the cotton fields are smaller and more isolated than is the case in Texas; consequently it is to be supposed that the spread of the pest will be retarded somewhat.

Basing estimates on a careful study of the distance the boll weevil has traveled each year, as well as upon some attention that has been paid to the means whereby it reaches new territory, referred to more in detail hereafter (p. 94), it seems safe to predict that in from fifteen to eighteen years the pest will be found throughout the cotton belt. During the time it has been in Texas there has been no tendency toward dying out, and in south Texas the pest is practically as troublesome, except in so far as it is affected by changes in managing the crop, as it was in 1895. In Mexico, where it has existed for a much longer period, it is apparently as plentiful as ever. Careful attention that has been paid to the study of parasites and diseases, as well as temperatures unfavorable to the insect, has failed to reveal any prospect that it will ever be much less troublesome than now. There will, nevertheless, be seasons from time to time in which the damage will be much less than normal. Climatic conditions will undoubtedly cause temporary diminution of the numbers of the pest in certain localities. In Texas these conditions have given rise almost every year to the supposition on the part of the planters that the insects have died out. This was especially the case in the region between San Antonio and Beeville in 1900, and in the vicinity of Corpus Christi in 1903. Both these years followed a series of seasons in which there was much less than the normal rainfall; consequently not only had a great many of the weevils been killed, but the numbers had been diminished by reason of the very limited extent to which it was possible to raise cotton. Both 1900 and 1903, however, were exceedingly favorable for cotton. Early planting was possible, and there was an abundance of rain throughout the season. The crop was so far advanced by the time the weevils became numerous that a very fair yield was made, although in neither of the cases was any top crop whatever produced. Whenever a series of years of scanty rainfall is followed by one of normal precipitation the weevil will temporarily be comparatively unimportant. The most disastrous seasons will be those in which the rainfall is excessive and planting unavoidably thrown late.

In this connection it becomes of some interest to speculate as to the possibility that the weevil may eventually be carried outside of the United States and gain a foothold in other cotton-producing countries. The fact that the insect is rather rapidly adapting itself to conditions in the United States that are quite diverse from those of its native home leads to the supposition that it would experience but little difficulty in adapting itself to climatic conditions wherever cotton may be grown. This probability of the spread of the weevil outside of the United States is increased by the fact that cotton seed for planting purposes is frequently shipped from the United States to various parts of the globe, and that within the last few years various conditions have caused especial interest to be displayed in this matter. There is nothing whatever to prevent weevils that may happen to be sacked with cotton seed from being carried long distances on shipboard. In the semidormant condition in which they hibernate they have often been known to go longer without food than is ordinarily required for a freight shipment from Galveston to Cape Town. Although there are no truly cosmopolitan cotton insects, it seems likely that the boll weevil may eventually be more widely distributed than any other.

LIFE HISTORY.

SUMMARY.

The egg is deposited by the female weevil in a cavity formed by eating into a square or boll. The egg hatches in a few days and the footless grub begins to feed, making a larger place for itself as it grows. During the course of its growth the larva sheds its skin at least three times, the third molt being at the formation of the pupa, which after a few days sheds its skin, whereupon the transformation becomes completed. These immature stages require on the average between two and three weeks. A further period of feeding equal to about one-third of the preceding developmental period is required to perfect sexual maturity so that reproduction may begin.

Variation in size depends directly upon abundance and condition of the food supply. Weevils of average size are about 8 mm. in length, one-third as broad as long, and weigh about one-fourth of a grain. Color varies as widely as does size. It is usually of a gray or yellow-brown, and is most markedly yellow in the largest weevils. Sexes are produced in practically equal numbers, the males predominating slightly. No other food has been found which will attract weevils from squares and no plant but cotton upon which they can sustain themselves for any considerable length of time. See Pl. II, fig. 12.

THE EGG.

The egg of the boll weevil is an unfamiliar object even to many who are thoroughly familiar with the succeeding stages of the insect. If laid upon the exterior of either square or boll it would be fairly conspicuous on account of its pearly white color. Measurements show that it is on the average about 0.8 mm. long by 0.5 mm. wide. Its form is regularly elliptical (Pl. III, fig. 14), but both form and size vary somewhat. Some eggs are considerably longer and more slender than the average, while others are ovoid in shape. The shape may be influenced by varying conditions of pressure in deposition and the shape of the cavity in which it is placed. The soft and delicate membrane forming the outer covering of the egg shows no noticeable markings, but is quite tough and allows a considerable change in form. Were the eggs deposited externally they would doubtless prove attractive to some egg parasite as well as to many predatory insect enemies. Furthermore, the density of the membranes would be insufficient to protect the egg from rapid drying or the effects of sudden changes in temperature. All these dangers the weevil avoids by placing the eggs deeply within the tissue of the squares or bolls upon which she feeds. As a rule, the cavities which receive eggs are especially prepared therefor and not primarily for obtaining food. Buried among the immature anthers of a square or on the inner side of one carpel of a boll, as they usually are, weevil eggs become very inconspicuous objects (Pl. I, fig. 3) and are found only after careful search.

EMBRYONIC DEVELOPMENT.

Owing to the transparency of the egg membranes, something of the development of the embryo can be seen through them, but no special study has yet been made upon the subject of the embryology of the weevil. The fully developed embryo completely fills the interior of the egg, its large head being in one end and its body curved ventrally upon itself till nearly double. Considerable motion is manifested if the egg be touched at this period.

LENGTH OF EGG STAGE.

Concealed as the eggs are beneath several layers of vegetable tissue, it is impossible to examine them to ascertain the exact length of the egg stage without in some degree interfering with the naturalness of the accompanying conditions. The beginning of the stage was easily obtained by confining female weevils with uninfested squares. Careful dissections were then made of the squares at a little later than what was found to be the average embryonic period at that season. In this way it is believed the range of error was reduced to a fraction of a day in most cases, and a large number of observations were made to still further reduce the error.

As shown by Table I, 553 observations have been recorded upon this point, the majority of the observations being made in the fall of 1902. Considering the temperatures prevailing at the four periods studied, it appears that the range in development during the average season at Victoria, Tex., has been included, and it seems probable that from these temperatures as a basis the length of the egg stage can be approximately determined for any season and for any locality within the present area of infestation.

TABLE I.—*Length of egg stage at certain periods.*

Period of examination.	Number of observations.	Mean temperature for period.	Average effective temperature.[a]	Average length of egg stage.
1902.		°F.	°F.	*Days.*
September 4–October 3	385	81	38	2.5 to 3
October 7–November 13	107	73	30	4 to 4.5
November 27–December 15	36	62	19	11
1903.				
May 27–June 5	25	72.5	32.5	3.5 to 4
Total	553			[b]3.4 to 4.1

[a] In considering the influence of temperature upon the weevils it has been assumed that, as has been found to be the case with other animals, 43° F. would be about the lowest temperature at which the weevils would be active. Temperatures below that point would have, therefore, no influence upon their activity, while all above that point would. For this reason it is better to speak of the "effective temperature," meaning by that the number of degrees above 43° F. Experiments made upon the influence of temperature upon the activity of weevils indicate that this is very near the correct figure for this insect.

[b] Weighted average.

The extreme range observed in Table II in the length of this stage is from two to fifteen days, while the average period for the whole number of observations is but three and six-tenths days. It is possible that the embryo can undergo an even greater retardation without losing its vitality.

It may be noted here that drying of the square will also retard embryonic development, but this condition does not occur in the field.

TABLE II.—*Range in length of egg stage.*

Number of eggs.	Length of egg stage.	Number of eggs.	Length of egg stage.
	Days.		*Days.*
2	2	4	5 to 6
132	2 to 3	3	8 to 9
192	{ 3 2 to 4	5 15	10 to 11 10 to 12
42	3 to 4	4	10 to 13
96	{ 4 3 to 5	3 2	13 to 14 13 to 15
40	4 to 5		
13	{ 5 4 to 6		

The length of the egg stage in bolls does not appear to differ greatly from that in squares.

HATCHING.

While still within the egg the larva can be seen to work its mandibles vigorously, and although a larva has never been seen in the act of making the rupture which allows it to escape from the egg, it is believed that the rupture is first started by the mandibles. The larvæ do not seem to eat the membranes from which they have escaped, but owing to the extreme delicacy of the skin it is almost impossible to find any trace of it after the larva has left it and begun feeding on the square.

HATCHING OF EGGS LAID EXTERNALLY.

It occasionally happens that females are unable to force an egg into the puncture prepared to receive it and the egg is left on the outside of the square or boll. Eggs so placed usually shrivel and dry up in a short time. To test the possibility of a larva making its way into a square from the outside, a number were protected from drying. Of the 19 eggs tested, 6 hatched in from two to three days. In no case, however, was the young larva able to make its way into the square and it soon perished. The hatching of eggs laid externally is of no importance, since the larvæ must perish without doing any damage.

EATING OF EGGS DEPOSITED OUTSIDE.

The number of eggs left outside increases as the female becomes weakened, and is especially noticeable shortly before her death. The number of such eggs which may be found is greatly diminished by the following peculiar habit, which was observed many times. Occasionally it appeared that the puncture which the female had made for the reception of an egg was too narrow to receive it, and after a prolonged attempt to force it down the female would withdraw her ovipositor, leaving the egg at the surface. She would then turn immediately and devour the egg. After that, seeming conscious of her failure and aware of the cause of it, she would proceed to find and enlarge somewhat the cavity previously made. When this was completed she would attempt to place another egg therein. The second attempt was usually successful, but in one or two cases a female was seen to fail several times, and in more than half of these cases she ate the eggs, as has been described.

PERCENTAGE OF EGGS THAT HATCH.

Definite records were not kept upon this point, but in the many hundreds of eggs followed during these observations very few failed to hatch, though some were much slower in embryonic development than were others laid at the same time and by the same female. It is the writers' general impression that less than 1 per cent of the eggs are infertile or fail to hatch.

THE LARVA.

DESCRIPTION.

The young larva, upon hatching from the egg, is a delicate, white, legless grub of about 1 mm. ($\frac{1}{25}$ inch) in length. Except for the brown head and dark-brown mandibles, the young larva is at first as inconspicuous as the egg from which it came. As it feeds and grows it continues to enlarge a place for itself in the square or boll until the food supply has become exhausted or the vegetable tissues are so changed as to be unsuitable for food. By this time, as a rule, the interior of the square has been almost entirely consumed and the larval castings are spread thickly over the walls of the cavity (Pl. III, fig. 15). This layer becomes firmly compacted by the frequent turning of the larva as it nears the end of this stage. In the cell thus formed occur the great changes from the legless grub to the fully formed and perfect beetle (Pl. I, figs. 7, 8, and 9).

Throughout this stage the body of the larva preserves a ventrally curved crescentic form (Pl. III, fig. 16). The color is white, modified somewhat by the dark color of the body contents, which show through the thinner, almost transparent, portions of the body wall. The dorsum is strongly wrinkled or corrugated, while the venter is quite smooth. The ridges on the dorsum appear to be formed largely of fat tissue. After becoming full-grown the larva ceases to feed, the alimentary canal becomes emptied, and both the color and form of the larva are slightly changed. The dark color disappears from the interior and is replaced by a creamy tint from the transforming tissues within. The ventral area becomes flattened, and the general curve of the body is less marked. Swellings may be seen on the sides of the thoracic region, and when these are very noticeable pupation will soon take place.

GROWTH.

It is impossible to follow the growth of an individual larva without interfering so greatly with its normal conditions of life as to make the observations unreliable. It seemed more accurate to measure larvæ of approximately known ages. In these measurements the natural curve of the body was not interfered with, but the measurement taken across the tips of the body. In this way it was found that in squares during the hot weather the length of the body increases quite regularly by about 1 mm. a day. As it becomes cooler the daily growth is less. In bolls which grow to maturity the rate of growth is less and the length of the growing period is much greater. Full-grown larvæ vary in length from 5 to 10 mm. across the tips of the curve. Larvæ of normal size in squares average from 6 to 7 mm. The largest larvæ are developed in bolls which grow to maturity (Pl. III, fig. 19).

MOLTS.

To accommodate the rapid growth of the larva two or three molts occur. The period of change from one instar or stage to the next is so short that the chances of opening a square at just the right time to observe the process are very small indeed. However, it has been ascertained beyond question that two molts occur before the larva reaches half its growth. The first occurs at about the second day and the second at about the fourth day. Whether a third molt occurs before pupation can not be positively stated; but having occasionally found larvæ which had certainly just molted, but which were much larger than the usual size at the second molt, the writer is led to suspect that three larval molts may sometimes, though possibly they do not always, occur. In bolls where the length of the larval stage is often three or four times as great as that usually passed in squares it seems almost certain that more than two larval molts occur regularly. Counting only the first two molts which have been often found, a third occurs at the time the larva pupates.

PROCESS OF MOLTING.

So little is known in regard to the molting of Curculionidæ that the process as observed is here recorded. In the cases observed, starting at the neck, the skin split along the back, and was then pushed downward and backward along the venter of the larva. The cast head shield remained attached to the rest of the skin.

Immediately after casting the skin the head, as well as the rest of the body of the larva, was of a pearly-white color. The tips of the mandibles first became brown, and within a short time a yellowish-brown color marked the entire integument of the head.

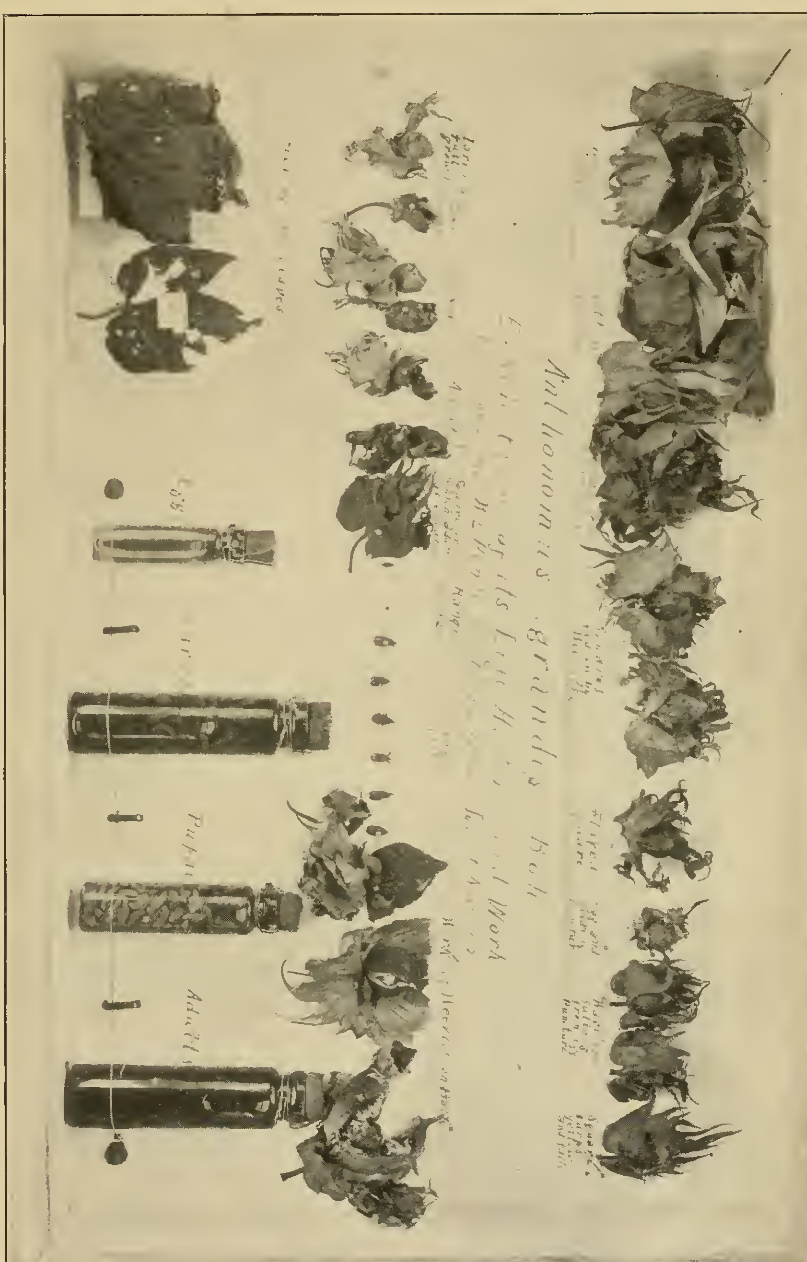
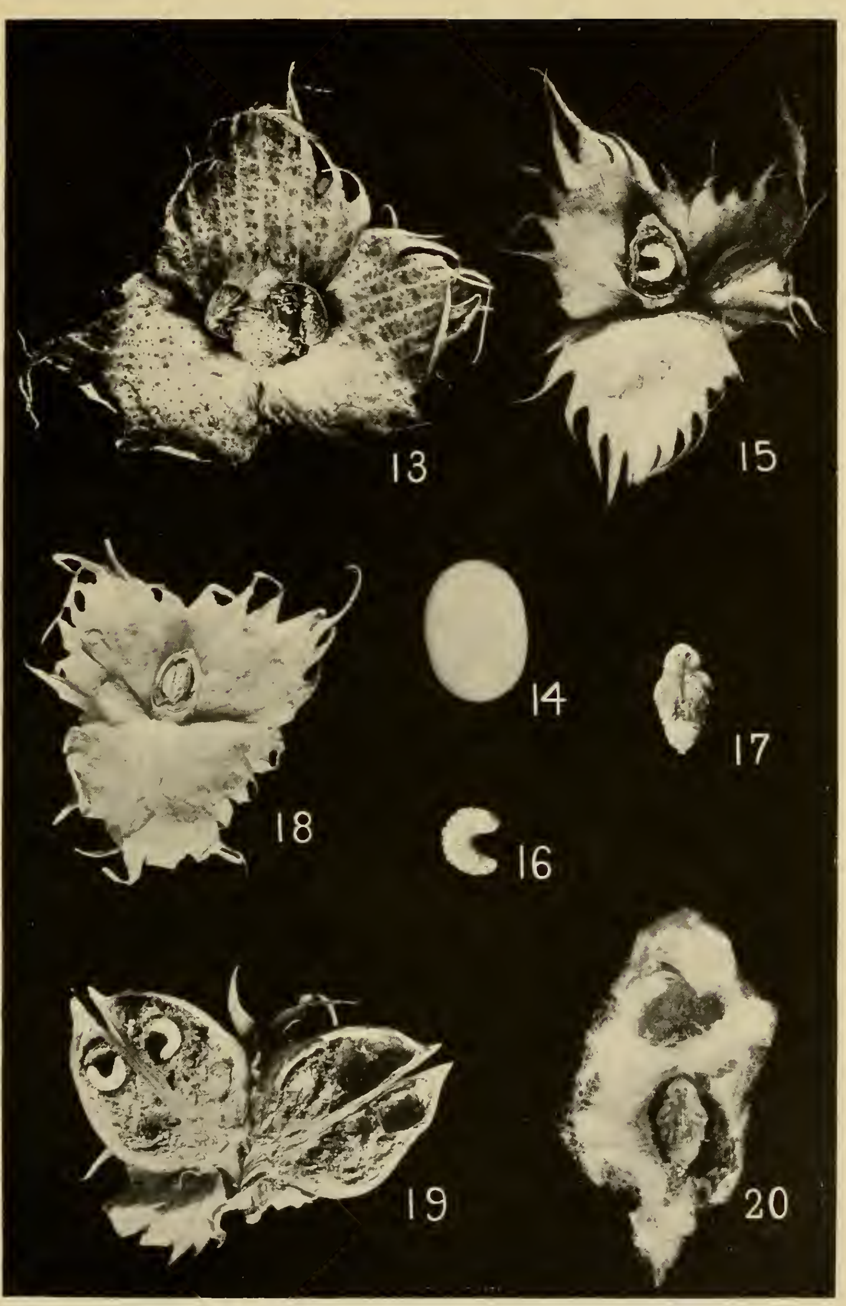


FIG. 12.—COLLECTION SHOWING LIFE HISTORY AND WORK OF BOLL WEEVIL. (ORIGINAL.)



DEVELOPMENTAL STAGES AND WORK OF THE BOLL WEEVIL.

Fig. 13, Two boll weevils feeding on a square, natural size; fig. 14, egg isolated, 25 times natural size; fig. 15, full-grown larva in square, natural size; fig. 16, full-grown larva isolated, natural size; fig. 17, pupa, twice natural size; fig. 18, adult just transformed, natural size; fig. 19, large larvæ in large boll, two-thirds natural size; fig. 20, pupal cell in boll, broken open, twice natural size. (Original.)

LENGTH OF LARVAL STAGE.

Most of the observations upon the larval stage were made between September 1 and December 15, 1902. The temperature prevailing during the first half of September was as high as is ordinarily experienced at Victoria during midsummer, and therefore the extremes of the average season may be considered as having been covered.

The time of egg deposition was easily determined by exposing uninfested squares in breeding cages containing active females. The time of hatching of the larva could only be found by opening the square, and it was so ascertained. The newly hatched larva was then placed in a small cavity made by lifting the covering on the side of a freshly picked square and removing one or two of the immature anthers. The coverings were then replaced as carefully as possible. Another disturbance was necessary to determine exactly the date of pupation. Observations made in this way were checked by others using larvæ which were allowed to go from egg deposition to pupation under natural conditions and without disturbance until the end of the larval stage was approximately reached. Since the sum of the times found for the various stages agrees approximately with the known length of the immature period in cases where no disturbance of normal conditions occurred, we may conclude that the periods found for the larval stage were approximately correct.

Altogether 266 observations were recorded upon the length of this stage. The majority of the observations may be included in three groups, and when thus grouped they may be best considered in relation to the effective temperature. Table III presents a brief summary of these groups:

TABLE III.—*General results as to length of larval stage in squares.*

Period of examination.	Mean average temperature.	Average effective temperature.	Number of observations.	Average range of stage.
1902.	°F.	°F.		Days.
September 6 to October 5	78.7	35.7	195	6 to 9
September 26 to October 21	73.6	30.6	15	7 to 12
November 11 to December 12	62.5	19.5	15	20 to 30

During the heat of summer the larval stage requires approximately one week. This time appears to hold so long as the mean average temperature remains above 75° F. As the temperature falls below that point there is a gradual increase in the length of this stage. The average total effective temperature required during hot weather by the larval stage is not far from 280° F. As development becomes retarded by colder weather the average total effective temperature required to complete it is much greater.

These facts may be expressed in general by stating that during the hottest summer weather the length of this stage is somewhat less than one week. Development becomes slower as the temperature falls, but does not cease altogether so long as cotton can live. Even frosts do not destroy larvæ in the squares and bolls, and these may finish development during warmer weather after the frost has taken place.

The length of the larval stage in bolls is as a rule much greater. If the boll falls when small the increase is slight, but if an infested boll grows on to maturity the larval stage more than any other is much extended. Special observations upon the larval stage in bolls have not been made, but reckoning from the known length of the whole developmental period in maturing bolls we may conclude that the larval stage can not be less than six or seven weeks.

PUPAL CELLS IN BOLLS.

As the boll approaches maturity, the full-grown larva ceases to feed upon the drying and hardening tissues of seed and fiber. Its excrement, more or less mixed with lint, becomes firmly compacted, and in the drying which occurs the mass forms a cell of considerable firmness, within which pupation and the subsequent transformation to the adult take place (Pl. III, fig. 20). These pupal cells frequently include a portion of the hull of a seed, but the writer has never found a large larva or a pupa entirely inclosed within a single cotton seed. The cells described are shorter and thicker than seeds, but in general appearance there is considerable resemblance between them (Pl. XI, fig. 44). Doubtless these cells have misled some into the statement that they have found weevils in cotton seeds.

PUPATION.

The formation of the adult appendages has gone a good way before the last larval skin is cast. The wing pads appear to be nearly half their ultimate size. The formation of the legs is also distinctly marked, and the old head shield appears to be pushed down upon the ventral side of the thorax by the gradual elongation of the forming proboscis. Finally the tension becomes so great that the tightly stretched skin is ruptured over the vertex of the head, and it is then gradually cast off, revealing the delicate white pupa. The cast skin frequently remains for some time attached to the tip of the abdomen.

THE PUPA.

When this stage is first entered the insect is a very delicate object both in appearance and in reality. Its color is either pearly white or cream. The sheaths for the adult appendages are fully formed at the beginning of the stage and no subsequent changes are apparent except in color (Pl. I, figs. 5 and 6). The eyes first become black, then the proboscis, elytra, and femora become brownish and darker than the other parts (Pl. III, fig. 17).

The final molt requires about thirty minutes. The skin splits open over the front of the head and slips down along the proboscis and back over the prothorax: The skin clings to the antennæ and the tip of the proboscis till after the dorsum has been uncovered and the legs kicked free. Then by violently pulling upon the skin with the fore legs first the tip of the snout and then the antennæ are freed, and finally the shrunken and crumpled old skin is kicked off the tip of the abdomen by the hind legs.

LENGTH OF PUPAL STAGE.

The length of this stage is more easily determined than that of any other. It seemed to make little difference in the time whether the pupæ were allowed to remain in the squares or removed therefrom. Considerable variation in the length of this stage exists among individuals of the same generation and even between offspring of the same female and from eggs laid on the same day. The period of investigation ranged from July to December, so that the extremes of the season are included. Altogether over 450 observations were made upon the length of this stage. Nearly all of these are included in Table IV, which shows a summary of the results.

TABLE IV.—*Tabular arrangement of observations upon the length of pupal stage in squares.*

Period of examination.	Number of observations.	Range in length of pupal stage.	Average length of stage.	Average effective temperature.	Total effective temperature.
1902.		*Days.*	*Days.*	° *F.*	° *F.*
July 6 to 31	161	2 to 5	3.5	39.65	138.8
September 15 to October 3	81	3 to 7	5.2	36.05	187.5
September 24 to October 28	167	4 to 8	6.0	31.1	186.1
November 2 to 13	29	5 to 6	5.6	26.2	146.7
December 2 to 29	4	10 to 16	14.5	18.55	269.0

It should be noted in connection with Table IV that the observations made in November were during a period of rather warm weather and that the temperature records for that time are incomplete. It is likely that the average effective temperature given for that period might be different were the records complete.

The average length of this period during hot weather is from three to four days, and the period increases as the cool fall weather approaches to a maximum of about fifteen days.

A comparison of Tables I, III, and IV shows that the decrease in temperature affects each stage in very nearly the same proportion. In each case the maximum recorded length of any stage is about four times its minimum, and the great retardation in each case occurs somewhere between 60° and 70° F. of mean average temperature, or 17° to 27° F. of effective temperature. Even greater retardation occurs during the winter season.

The length of the pupal stage in large bolls has not been determined. It appears to be longer than in squares, but it certainly can not occupy the same proportional part of the entire developmental period that it does in squares.

EFFECT OF BURYING SQUARES UPON PUPATION AND THE ESCAPE OF ADULTS.

The experiments made upon this point were designed to ascertain the value, if any, in the plowing under of squares as a means of destroying the larvæ and pupæ infesting them. But few experiments seemed necessary to demonstrate the futility of this operation alone as a means of controlling the weevil.

Squares which were known to be infested with about half-grown larvæ were placed in glass jars and covered with several inches of quite dry and fairly well pulverized earth. When examination was made it was found that pupation had taken place normally while the squares were buried under from 2 to 5 inches of dirt. In no case was pupation prevented, though a few weevils did not leave the squares after having become adult. Altogether about 100 squares were thus buried, and from them over 75 weevils emerged.

In a portion of the preceding tests careful examination was made to ascertain how far toward the surface the newly emerged weevils had succeeded in getting before they perished. It should be noted that these weevils had never fed, and they would have, therefore, less strength and endurance than such fully hardened adults as might be buried in the ordinary processes of field cultivation. Furthermore, the soil used was of finer texture and more compactly settled than it would be in the field. Twenty-seven weevils were found in this examination, their location varying from the bottom of the jar to their having escaped through 4 inches of soil. A weighted average shows, however, that each weevil had made its way upward through 2 inches of dirt. We may infer, therefore, that had these squares been buried under less than 2 inches of fairly well pulverized earth, as would be the case from field cultivation, but a small percentage of them would have failed to make their way out. As it was, fully three-fourths of those leaving the squares made their way out through more than 2 inches of dirt.

In 1896 Mr. C. L. Marlatt noted that "the weevils can escape from loose soil when buried to a depth of 3 inches, but when artificially embedded 8 inches in moist soil they are unable to extricate themselves, as shown by test experiment." Quite extensive experiments are now being made at Victoria to test the ability of the fully fed adult weevils to escape after being buried at various depths and in soil containing various percentages of water. That the moisture content exerts a great influence upon the texture of the soil is especially noticeable in the black bottom lands of the Texas cotton belt. While the results of these experiments may furnish reasons for changing our conclusions upon this point, the present indication is that the beneficial effect of thorough cultivation lies in the direct influence which that practice exerts upon the steady and rapid growth of the cotton, thus favoring the production of squares, the setting of bolls, and the early maturity of the crop rather than in the direct destruction of the weevils by burying them either while in the squares or after they have become adult.

THE ADULT.

BEFORE EMERGENCE.

Immediately after its transformation from the pupa the adult is very light in color and comparatively soft and helpless. The proboscis is darkest in color, being of a yellowish brown; the pronotum, tibiæ, and tips of the elytra come next in depth of coloring. The elytra are pale yellowish, as are also the femora. The mouth parts, claws, and the teeth upon the inner side of the fore femora are nearly black. The body is soft and the young adult is unable to travel (Pl. III, fig. 18), consequently this period is passed where pupation occurs. Usually two or more days are required to attain the normal coloring and the necessary degree of hardness to enable the adult to make its escape from the square or cell.

EMERGENCE.

The normal method of escape from squares and small bolls is by cutting with its mandibles a hole just the size of the weevil's body (Pl. IV, fig. 21). In large bolls the escape of the weevil is greatly facilitated by the natural opening of the boll (Pl. IV, fig. 22). Often the pupal cell is broken open by the spreading of the carpels, and when this is the case the pupa, if it has not already transformed, becomes exposed to the attack of enemies or, what is probably a more serious menace, the danger of drying so as to seriously interfere with a successful transformation. If the cell remains unbroken the weevil always escapes by the path of least resistance, cutting its way through as in the case of a square (Pl. IV, fig. 26). The material removed does not appear to be eaten, but is rather cast aside and left within the cell as a mass of fine débris.

CHANGES AFTER EMERGENCE.

At the time of emergence the weevils are comparatively soft, and they do not attain their final degree of hardness for some time after they have begun to feed. If they never feed they never harden. The color of the chitin is of an orange tinge at the time the weevils leave the squares or bolls, but after exposure for some time it turns to a dark chocolate brown. The development of the hair-like scales is probably entirely checked by the drying of the chitin, but the darkening of the ground color makes the scales more apparent, and thus gives the impression of further development after emergence has taken place.

SIZE OF WEEVILS.

Size of boll weevils is an especially variable quantity, and, as usual, varies almost directly in proportion to the abundance of the larval food supply and the length of the period of larval development. The extremes are so great that the smallest and largest weevils would be thought by one not thoroughly familiar with them to be of entirely different species. So far as dimensions may convey an idea of the size, we may say that the weevils range from 3 to 8 mm. ($\frac{1}{8}$ to $\frac{1}{3}$ inch) in length, including the proboscis extended, and from 1 to 3 mm. ($\frac{1}{25}$ to $\frac{1}{8}$ inch) in breadth at the middle of the body. (See Pl. I, fig. 1.)

RELATION OF SIZE TO FOOD SUPPLY.

The smallest weevils are developed from squares which were very small, and which, for some reason, either of plant condition or of additional weevil injury, fell very soon after the egg was deposited. The supply of food was not only small, but, owing to the immaturity of the pollen sacs, its quality was also poor. Normally squares continue to grow for a week or more after eggs are deposited in them, and such squares produce the weevils of average size and color.

The largest weevils are produced in bolls which grow to maturity. In them the food supply is most abundant, and the period of larval development is several times as long as it is in squares. Possibly these differences in size may be better shown by a summary of observations which were made upon the weight of adults.

WEIGHT OF ADULTS.

The weevils used in these experiments were bred to insure their coming from the proper source. After emergence they were fed for some time to bring them up to their normal weight.

TABLE V.—*Summary of weight of weevils.*

Source of weevils.	Number.	Average weight.
		Grain.
Bred from picked small squares	25	0.105
Bred from average fallen squares	68	.231
Bred from large bolls	69	.268
Total	162	36.825
Average weight per weevil, all sources		.227

It should be noted that these figures do not nearly represent the weight of the extremes in size, but they do indicate the difference in the average weevil of each class.

COLOR.

Color is very often a variable character in insects, and the boll weevil presents considerable range in this respect. Whatever influences the size of the larva affects directly the size of the adult, and it is noticeable that weevils of the same size are also, as a rule, closely alike in color. In general, the smaller the size of the weevil the darker brown is its color; the largest weevils are light yellowish brown. Between these two extremes are the majority of average-sized weevils, which are either of a gray-brown or dark yellow-brown color. Weevils developing in large bolls, having an abundant food supply and a developmental period averaging more than twice that of weevils in squares, are larger in size and more yellowish in color than are those from squares.

The principal reason for the variation in color lies in the degree of development of the minute hair-like scales, which are much more prominently developed in the large than in the small specimens, although the color of old specimens is often changed by the rubbing off of the scales. The scales are yellow in color, while the ground color of the chitin bearing them is a dark brown or reddish brown. When the scales are but slightly developed, as seems to be the case with small weevils produced from underfed larvæ, the dark-brown ground color is predominant, while in the case of large weevils produced from larvæ having abundant food and a long period of development the scales are largely produced and give the strong yellow tone to the color which is characteristic of them.

The development of the scales appears to take place mostly after the adult weevil has become quite dark in color but before it becomes fully hardened. They seem, therefore, to be a sort of non-essential aftergrowth which depends upon the surplus food supply remaining after the development of the essential parts of the weevil structure.

SIZE AND COLOR NOT INDICATIVE OF SEX.

Eminent coleopterists have studied the boll weevil most carefully with the purpose of discovering some external character by which the sexes could be distinguished, but all have failed to find any reliable points of distinction. The writer therefore does not hesitate to own that he also has failed to find any reliable character for the distinction of the sexes. Many persons have the idea that the small dark weevils are males and the larger and lighter-colored brownish-yellow weevils are females. This idea is a mistaken one. In general it is probably true that the males are slightly smaller than the females, but judging from determinations of the sex of many hundreds of weevils it may be stated positively that size and color are characters which are related to food supply and length of the period of development and are not indications of sex. The sexes seem to be about equally represented among the smallest as well as the largest weevils.

Characters commonly used to separate the sexes in the family Curculionidæ are not distinctive in this species. As a rule the antennæ are inserted nearer the tip of the snout in the male than in the female. This character is variable among boll weevils; and though a large number of accurate measurements might show that a slight difference generally exists, it is too inconspicuous a character to be of general use. With most species the top of the rostrum of the male is rougher than is that of the female. However it may be with other species, there is but little if any difference in this respect between the young adults of the boll weevil. As the individuals become older the greater activity of the females serves to wear the roughness from the top of the rostrum, and thus gradually, as a result of different habits, this character becomes more distinctive. In less than half of the boll weevils, however, is this character sufficiently noticeable to separate the sexes. The terminal segment of the abdomen shows no external difference in either sex, although in many weevils important characters are there found.

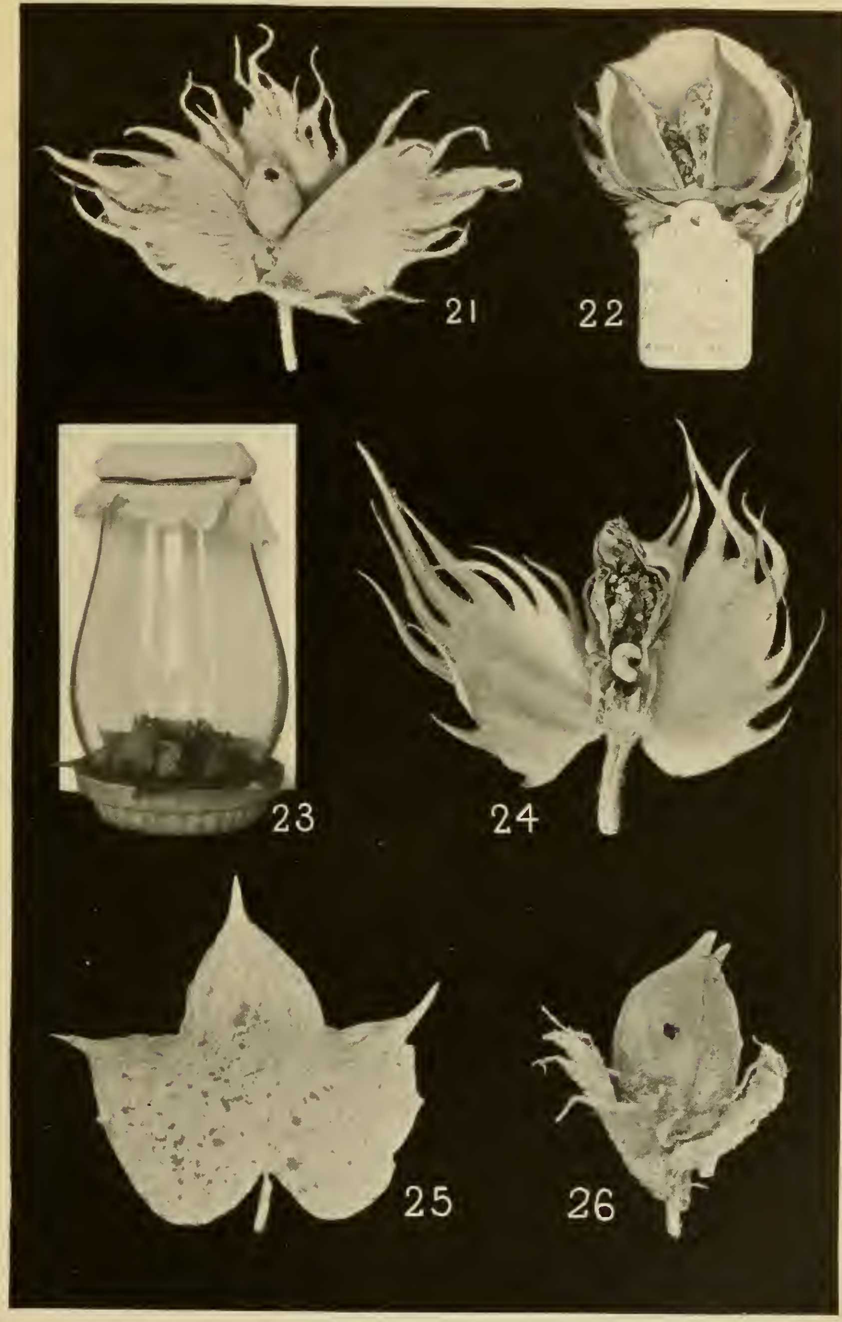
PROPORTIONS OF THE SEXES.

No reliable secondary sexual characters having as yet been discovered, the certain determination of sex therefore rests solely upon the primary characters, thus requiring a certain amount of dissection in each case. Such determinations have been made upon large numbers of weevils taken in the field and upon many bred in the laboratory at various seasons of the year. The results are briefly summarized in Table VI.

Table VI.—*Proportions of the sexes.*

	Number of males.	Number of females.
Season of 1902, both bred and from field	240	260
Hibernated weevils, 1902–3	269	174
First generation, 1903	43	32
Bred weevils, 1903	45	33
Field weevils, midsummer, 1903	52	59
Total	649	558

From these 1,207 determinations it appears that males are somewhat more numerous than females, the percentage being nearly 54 of males to 46 of females. It is noticeable, however, that the only season at which a preponderance of males occurs is during late fall. If we exclude the figures for hibernated weevils for a moment, we find that the totals for the balance of the season are remarkably close for the two sexes, being 380 males and 384 females. It seems safe to say, therefore, that the sexes are practically equal in numbers except that more males than females seem to be found among hibernating weevils. It may be that the retardation of development due to approaching



BREEDING JAR AND METHOD OF ESCAPE OF ADULTS FROM SQUARES AND BOLLS.

Fig. 21, Emergence hole made by weevil in square, natural size; fig. 22, weevil escaping normally from boll, two-thirds natural size; fig. 23, apparatus used in breeding weevils, one-fourth natural size; fig. 24, larva destroying the ovary and preventing the bloom in large squares, natural size; fig. 25, leaf fed upon by weevils in confinement, one-half natural size; fig. 26, emergence hole of weevil from boll which never opened, two-thirds natural size. (Original.)

FIG. 27.—LARVA IN SQUARE, OVARY UNTOUCHED, NATURAL SIZE. (ORIGINAL).

FIG. 28.—LARGE AND SMALL LARVÆ IN BOLL, TWO-THIRDS NATURAL SIZE. (ORIGINAL.)

cold weather favors the development of males. Not only was there a larger number of males than of females taken in December, 1902, but there were also more males than females taken in the field in the spring of 1903 among the hibernated weevils which lived through the winter. According to the determinations made, 64 per cent of the 259 weevils dying during the winter were males and 56 per cent of the weevils living through the winter were also males. Since it appears that females require fertilization in the spring before they begin to deposit eggs, the preponderance of males at that time acts as a provision to insure the propagation of the species.

LENGTH OF LIFE UPON SQUARES.

The observations made along this line may be divided into eight groups, each dealing with some special food condition or class of weevils. For the confinement of weevils in the laboratory the most satisfactory apparatus tried, both for convenience in handling and for the maintenance of favorable conditions for the weevil, was made up as follows: A 4 or 5 inch shallow earthen saucer, such as is used with flowerpots, was filled with soil, which was kept fairly moist. Over this was placed a fresh cotton leaf, which conserved the moisture from the soil, but never became wet, and kept both weevils and squares clean, besides facilitating the handling necessary to frequent renewals of the food supply and the consequent transference of the weevils. The rest of the cage was formed by an ordinary lantern globe covered at the top by cheese cloth held firmly in place by a rubber band. With this apparatus weevils could be readily observed without disturbing them, and food supplied was kept in good condition and could be easily renewed, while there were no cracks to hide in or to allow weevils to escape (Pl. IV, fig. 23). The moisture of the soil and fresh leaf covers were renewed as needed. Clean squares were supplied each day, and the actual number of egg and feeding punctures recorded upon numbered slips kept with each cage. The sex of each weevil was also determined and noted upon its death, thus giving an accurate record of the number and sex of weevils responsible for the punctures recorded. Most of the weevils used were bred, so that the exact length of their lives is known. Length of life refers only to adult life from the time of emergence from the square or boll to the death of the weevil. Many weevils brought in from the field were under observation in the laboratory for periods sufficiently long to justify the inclusion of the results obtained from them with those of weevils which were bred. Obviously the time these were under observation does not represent their true length of life; therefore the inclusion of both results renders the averages obtained the more conservative.

21739—No. 45—04——3

TABLE VII.—*Length of life of weevils upon squares.*

	Males.		Females.	
	Number.	Average days.	Number.	Average days.
Weevils placed in hibernation Dec. 15, 1902; living Apr. 15, 1903	23	180	14	171
Hibernated weevils taken spring, 1903; estimated adult Dec. 15, 1902	66	223	53	220
Hibernated weevils, from time of feeding in 1903	23	57	16	37
	67	88	52	80
First generation, bred	30	58	25	56
Third generation, bred	18	43	10	54
Fifth generation, bred	9	76	9	54
Totals and weighted averages, including hibernation period	146	151	111	148
Totals and weighted averages, not including hibernation period	147	71	112	64
Entire length of life, hibernated weevils only	89	212	67	210

Whether we include the time of hibernation or not, it appears from the averages of 156 hibernated weevils that those which winter successfully are longer lived than any following generation, as their active life in spring averaged fully 80 days for males and 70 for females. Probably the greater activity of the first generation may account for their somewhat shorter life. The average active life period for all generations is probably not far from 71 days for males and 64 days for females.

LENGTH OF LIFE ON BOLLS ALONE.

As weevils appear to feed freely on bolls in the field after the period of maximum infestation has been reached (Pl. I, fig. 10), these tests were made to determine whether they might be able to live normally with no other food.

A number of weevils were placed upon bolls as soon as they became adult. Others which had first been fed upon squares were given bolls after they had become hard and had shown themselves to be in a normally healthy condition. Of the total 37 weevils thus tested, 16 were males and 21 were females. The males showed an average length of life of 19.7 days, while the females survived for only 15.2 days. This is a much shorter period than the normal length of life upon squares for either sex.

LENGTH OF LIFE ON COTTON LEAVES ALONE.

To determine whether they could live upon the foliage of cotton alone 69 newly transformed weevils were at the 1st of October, 1902, placed upon fresh leaves, which were renewed at frequent intervals. During the first three weeks 52 of these weevils (21 male and 31 female) died, leaving 17 alive and well; 11 of these were then returned to squares and 6 continued upon the leaves. Of these 6, 3 lived to be 81 days old and were then intentionally killed for dissection. The average length of life of those kept entirely upon leaves was over 30 days. These results show clearly the ability of many of the weevils to live upon foliage alone in fields in which fall grazing is practiced until it becomes sufficiently cold for them to go into winter quarters (see Pl. IV, fig. 25).

LENGTH OF LIFE WITH SWEETENED WATER AND WITH MOLASSES.

So much has been said about the attraction of molasses for the weevils that tests were made with a cheap grade of molasses diluted with from 20 to 25 parts of water to see whether this solution really served them as food. The weevils used were just adult and had taken no other food. They fed quite readily upon the solution, remaining quietly with their snouts in the water for from a few minutes to an hour and a half at a time. The solution did not seem to draw them from any distance, but as soon as a weevil came to it it would stop to drink. Feeding or drinking took place daily or oftener until the death of the weevils. The average length of life for the 12 weevils used was a little less than 6 days.

As weevils without food but with water lived an average of 5½ days, the conclusion is that a solution of molasses 1 to water 25 parts does not serve the weevil as food, since it does not noticeably prolong life.

Six weevils just emerged kept upon undiluted molasses showed a greater length of life, these dying at an average age of 11½ days.

LENGTH OF LIFE WITHOUT FOOD, BUT WITH WATER.

These observations were made during August as a check upon those without water. The 8 weevils used were just adult and had never fed. Each weevil drank for one or two minutes at least once each day so long as it lived. All died at nearly the same time, having lived for an average of about 5½ days. As those without water lived an average of 5 days, it appears that access to water in the absence of food does not materially increase the length of life of the starving weevils.

LENGTH OF LIFE WITHOUT FOOD OR WATER.

Three series of observations were made along this line. In the first the weevils used were taken immediately after emergence and never allowed to feed. Fifty weevils were tested in this way during July and August and showed an average length of life of 5 days from the date of emergence. A few lived as long as 8 or 9 days. These never acquired as dark a color nor as great a degree of hardness as is normal.

In the second series the 15 weevils used were 7 weeks old and full-fed at the time of beginning the test. These showed an average length of life of slightly over 6 days, the range being from 5 to 9 days. These weevils were tested during the latter half of November, and the lateness of the season, together with the full-fed condition of the weevils, seemed to promise a considerably longer period than 6 days.

In the third series the 18 weevils used were 1 month old and full-fed at the beginning of the test in the middle of November. The conditions in this series were as in the series preceding, with the exception that an abundance of two species of grass taken from cotton fields was included. These weevils showed an average length of life of nearly 7½ days, ranging from 3 to 10 days. The weevils made no effort to feed upon the grass, so the slightly longer life period must be due to other causes.

CANNIBALISM.

It is hardly proper to speak of cannibalism as a food habit of the boll weevil, but the facts observed may well be recorded here. Under the impulse of extreme hunger weevils have several times showed a slight cannibalistic tendency.

Seven beetles were confined in a pill box without food. On the third day 6 only were alive. Of the seventh only the hardest chitinized parts (head, proboscis, pronotum, legs, and elytra) remained, the softer parts having been eaten by the survivors.

In another box containing 12 adults the leaf supplied for food was insufficient, and on the fourth day 8 were dead, 4 were partly eaten, and others had lost one or more legs each.

In another case a few young adults and a number of squares containing pupæ were placed in a box together with a few fresh squares to serve as food for the adults. When the box was opened after a number of days, one "reddish-brown" adult was found having its elytra eaten through and most of its abdomen devoured. In spite of this mutilation the victim was still alive and kicking slowly. The squares were still fresh and fit for food, so that this is really the clearest case of cannibalism observed.

Frequently more than one larva hatches in a square, and when this is the case a struggle between them is almost certain to take place before they become full grown. Many cases have been observed in which squares contained one living and one or more smaller dead larvæ, while in a few cases the actual death struggle was observed.

HABITS.

Among the habits of any insect of economic importance, the first for careful study are those relating to its food, and secondly those connected with its propagation. The study of the life history of the boll weevil has revealed no especially vulnerable point, but rather the important fact that in all its stages it is better protected against the attacks of enemies and the ordinarily effective remedies recommended by the economic entomologist than any other insect which has ever threatened the production of any of the great staple crops of this country. Naturally, then, we must needs turn to a study of the habits of the pest to point the way to means by which either it may be itself destroyed or its great destructiveness prevented.

FOOD HABITS.

LARVAL.

It is plainly the intention of the mother weevil to deposit her egg so that the larva upon hatching will find itself surrounded by an abundance of favorable food. In the great majority of cases this food consists principally of immature pollen. This is the first food of the larva which develops in a square, and it must be both delicate and nutritious. Often a larva will eat its way entirely around a square in its pursuit of this food. In most cases the larva is about half grown before it feeds to any extent upon the other portions of the square. It may then take the pistil and the central portion of the ovary, scooping out a smoothly rounded cavity for the accommodation of its rapidly increasing bulk (Pl. I, fig. 7; Pl. III, fig. 15; Pl. IV, fig. 24). So rapidly does the larva feed and grow that in rather less than a week it has devoured two or three times the bulk of its own body when fully grown. It sometimes happens that the square is large when the egg is deposited therein, and the bloom begins to open before the injury by the larva is sufficient to arrest its development. In many cases of this kind the larva works its way up into the corolla and falls with it, leaving the young boll quite untouched (Pl. V, fig. 27). Occasionally the flower opens and fertilization is accomplished before any injury is done the pistil, and in rare cases a perfect boll results from a truly infested square. Sometimes the larva when small works its way down into the ovary before the bloom falls, and in such cases the boll falls as would a square.

In large bolls the larvæ feed principally upon seed and to some extent upon immature fiber. A larva will usually destroy but one lock in a boll, though two are sometimes injured (Pl. V, fig. 28).

ADULT.

Before escaping from the square the adult empties its alimentary canal of the white material remaining therein after the transformation. The material removed in making an exit from the cell is not used as food, but is cast aside. Weevils are ready to begin feeding very soon after they escape from the squares or bolls in which the previous stages have been passed. For several days thereafter both sexes feed almost continuously and seem to have no other purpose in life. They will take squares, bolls, or leaves, but they much prefer the squares, and when squares are present in the field it is probable that leaves are seldom touched. As has been shown, however, weevils can live for a long time upon leaves alone when squares and bolls are wanting. Bolls are only slightly attacked so long as there is an abundance of clean squares.

The method of feeding is alike in both sexes. The mouth-parts are very flexibly attached at the tip of the snout (fig. 2) and are capable of a wide range of movement. The head fits smoothly into the prothorax like the ball into a socket joint and is capable of a considerable angle of rotation. The proboscis itself is used as a lever in prying and helps to enlarge the puncture through the floral envelopes especially. Feeding is accomplished by a combination of movements. The sharply toothed mandibles serve to cut and tear, while the rotation of the head gives the cutting parts an auger-like action. The forelegs especially take a very firm hold upon the square and help to bring a strong pressure to bear upon the proboscis during certain portions of the excavating process. The outer layer of the square, the calyx of the flower, is naturally the toughest portion that they have to penetrate, and only enough is here removed to admit the snout. After that is pierced the puncture proceeds quite rapidly, combinations of chiseling, boring, and prying movements being used. While the material removed from the cavity is used for food, the bulk of the feeding is upon the tender, closely compacted, and highly nutritious anthers or pollen sacs of the square. When these are reached the cavity is enlarged, and as much is eaten as the weevil can reach. The form of the entire puncture becomes finally like that of a miniature flask.

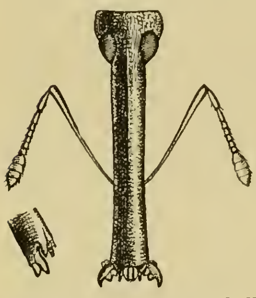


FIG. 2.—Mexican cotton boll weevil, head showing rostrum with antennæ near middle and mandibles at end—much enlarged (original).

Only after weevils have fed considerably do sexual differences in feeding habits begin to appear (Pl. III, fig. 13), the females puncturing mainly the base and the males the tip of the square.

Feeding punctures are much larger and deeper than are those made especially for the reception of the eggs (Pl. I, fig. 3); more material is removed from the inside of the square or boll and the opening to the cavity is never intentionally closed. Feeding punctures are most frequently made through the thinner portion of the corolla not covered by the calyx. The exposed tissue around the cavity quickly dries and turns brown from the starting of decay. As a number of these large cavities are often formed in one square (Pl. VI, fig. 29), the injury becomes so great as to cause the square to flare immediately, often before the weevil has ceased to feed upon it. Squares so severely injured fall in a very short time. The injury caused by a single feeding puncture is often overcome by the square and its normal course of development is continued. When feeding punctures are made in squares which are nearly ready to bloom, the injury commonly produces a distorted bloom (Pl. VI, fig. 30) and in very severe cases the boll will drop soon after setting.

After the females begin to oviposit their feeding habits become quite different from those of the males. Up to this time both sexes move but little, making a number of punctures in a single square; but from this point we must consider the feeding habits of the sexes separately.

MALE.

Studies of the feeding habits of males have been made both in the laboratory and out of doors. In the laboratory 65 males were under observation during a total period of 2,492 weevil-days.[a] During this period 2,185 squares were supplied them and they made 5,617 feeding punctures in 1,582 of these squares. A little calculation shows that they averaged to make $3\frac{1}{2}$ feeding punctures in each square, at the rate of $2\frac{1}{4}$ punctures a weevil each day. These observations were in most cases made during the latter part of each weevil's life. During the first few days they have often been found to make from 6 to 9 punctures a day. A general average of 3 feeding punctures a day in the laboratory would seem to be near the actual figures during the warm weather.

As each male while under observation attacked only about 2 squares every 3 days, the destructiveness of males seems comparatively slight.

Five males were followed upon plants under a field cage for a total period of 145 weevil-days. During this period they attacked 68 squares, making therein a total of 177 feeding punctures. This means an average of 2.6 punctures per square and an average of 1.2 punctures per male per day, making the number of squares attacked by each male less than 1 every 2 days. These outdoor observations indicate that the laboratory results, small though they appear, are yet higher than the actual field numbers. Whether in or out of doors, the activity of feeding decreases as the male grows older.

Males choose to puncture more often than do females through the tip portion of the square not covered by the calyx. The yellow or orange colored excrement is abundant, and owing to the somewhat sedentary habits of the males it accumulates often in quite large masses.

FEMALE.

After they begin to oviposit females seem generally to feed less upon one square or in one puncture than they do previous to that time. They obtain quite a considerable portion of their food from the excavations which they make for the deposition of their eggs, and as they show a strong inclination to oviposit only in clean or previously uninfested squares, their wandering in search of such squares

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[a] The term "weevil-day" is used for convenience to designate the product of the two factors; number of weevils multiplied by the number of days.

keeps their punctures scattered so long as plenty of clean squares can be found. When clean squares become scarce, the normal inclination can not be followed out, and the number of punctures made in one square will be greatly increased. Most of the special feeding punctures of females appear to be made either in the early morning or near sundown, the middle and warmest portion of the day being given mainly to egg deposition. The total amount of feeding done is really very large, as is shown by a few figures.

MALES AND FEMALES TOGETHER.

During the season of 1903 a large number of weevils was kept in the laboratory for special study, but as several weevils were confined in each cage, the work of the sexes can not be positively separated. A comparison of the results can best be made by means of a tabular arrangement of the figures.

TABLE VIII.—*Number of punctures per weevil per day.*

Characterization of lot.	Number of males.	Number of females.	Total.			Average.		
			Weevil days.	Feeding punctures.	Egg punctures.	Feeding punctures per weevil day.	Egg punctures per female day.	Period of observation.
								Days.
Hibernated weevils in laboratory	55	54	4,938	17,406	5,702	3.5+	2.3+	45.3+
Hibernated females in field cage		4	93	284	489	3.0+	5.3−	23.3−
Weevils of first generation in laboratory	31	27	3,258	16,487	3,565	5.0+	2.4−	56.2−
Females, first generation, in field cage		5	70	263	435	3.8−	6.2+	14.0
Males only, laboratory, summer of 1903	65		2,492	5,617		2.3−		38.3+
Total	151	90	10,851	40,057	10,191			

FEEDING OF HIBERNATED WEEVILS ON EARLY COTTON.

During the period in which hibernated weevils were coming from their winter quarters and seeking their first food, frequent examinations were made in fields where the cotton was most advanced to learn the first-food habits of such weevils. From statements made by previous investigators the writer is led to believe that the season of 1903 at Victoria was abnormal in respect to the small number of hibernated weevils which were to be found upon the young cotton in the field. The most careful search failed to discover more than a very few weevils, whereas at the same season in some years hibernated weevils have been picked in large numbers from the young cotton growing in the infested territory.

Whether they be few or many, however, makes no difference in the feeding habits of the hibernated beetles. The stage of the cotton determines largely the nature of the food habits at this time. Owing to the extremely wet winter and the very late spring of 1903, little cotton could be planted until the latter part of March or the first part of April. In such a season as this, therefore, cotton must be small at the time of the emergence of the weevils from hibernation, and some time must elapse before the formation of the first squares furnishes the weevils with their normal food supply. During this interval the weevil gets most of its food from the tender, rapidly growing terminal portion of the young plants, as several observers have noted. The central bud, young leaves, or the tender stems are attacked and upon these the weevils easily subsist until squares are developed, after which they confine their injury to them.

The earliest plants in a field seem to attract most of the weevils, and where seppa[a] plants occur they serve as excellent traps to draw the first attacks. Thus, in the spring of 1895 Mr. E. A. Schwarz found the first emerged hibernated weevils working upon seppa plants which had sprung from 2-year-old roots. These plants seem to start earlier and grow more vigorously than do those from seed and are therefore doubly tempting to the hungry weevils.

In 1896 Mr. Marlatt noted "the eating in the field on volunteer cotton is practically confined to the young expanding leaves at the bud and to the tender petioles or stems of this portion of the plant."

In the spring of 1903, in one field of comparatively early cotton, 2 or 3 acres in extent, the writer found, between April 24 and May 11, 23 weevils working on the buds and tender leaves of seppa plants before a single weevil was found upon the young planted cotton having from 4 to 8 leaves.

If, however, the cotton should be further advanced at the time the weevils appear, they would then go at once to the squares. Even then they prefer to attack the most advanced plants, which have a number of nearly grown squares, rather than the smaller plants which are but just beginning to square. Seppa plants, where such exist, come in, therefore, for a large part of the first attack of the hibernated weevils. This fact is well shown by observations made by Mr. A. N. Caudell, of the Division of Entomology, at Victoria, at about the middle of June, 1902. In an examination of 100 seppa plants growing in a planted field he found that fully half of the squares upon those plants were then infested. The planted cotton was just beginning to form squares, and was but slightly injured at that time.

INCREASE IN LEAF AREA OF COTTON.

The advisability of making observations upon this point was suggested by the attempts made to poison hibernated weevils by spraying early cotton with an arsenical insecticide. As the weevils fed so

[a] "Seppa" is the term used by the Mexican residents of South Texas to differentiate the cotton plants springing from the roots of the previous year from those strictly "volunteer," springing from accidentally scattered seeds.

exclusively in the most recently unfolded growing portions at the tips of the stems, it was evident that the rapidity of increase in the leaf area would at least indicate the frequency with which spraying would have to be repeated in order to keep in a poisoned condition the very limited portion upon which the weevils fed.

Although the observations were made after midsummer, the plants used were of the right size to indicate the points desired. Two series, each including five average plants, were selected.

The plants used in Series I had 8 leaves at the time of the first observation. Those used in Series II were older and averaged about 30 leaves each. The leaves borne upon the main stem were classed as primary and those from side branches as secondary leaves. Upon the date of each of the 5 observations made, the number of leaves in each class was ascertained, an average leaf in each class was quite accurately measured, and the total product of numbers and area thus found was considered as the approximate leaf area of the plant. The error has been reduced as much as possible by taking an average of the 5 plants in each series as representing a typical plant, and it is with these results that comparisons have been made.

TABLE IX.—*Estimated increase in leaf area of cotton, averages of five plants.*

Date of examination.	Primary leaves.			Secondary leaves.		
	Average number per plant.	Average area, plant.	Percentage of daily increase.	Average number per plant.	Average area, plant.	Percentage of daily increase.
1902.						
Series I:		*Sq. in.*			*Sq. in.*	
August 30	8.0	64.0		0.0		
September 13	8.6	136.8	8.0	8.0	41.2	
September 25	9.8	231.6	5.4	16.6	187.4	30.0
October 6	11.0	309.6	3.0	22.6	347.8	7.8
October 17	13.2	376.6	2.0	31.0	522.4	4.6
Series II:						
August 30	7.8	177.2		21.6	266.8	
September 13	8.4	229.2	2.0	24.8	341.4	2.0
September 25	9.8	241.6	.04	42.4	514.0	3.6
October 6	9.6	214.8	[a]−1.0	52.6	619.2	1.8
October 17	10.0	216.8		67.4	808.8	2.1

[a] Decrease of 1 per cent due to falling of old primary leaves.

Several facts are evident from an examination of this table. After the plant has acquired about eight primary leaves the formation of branches and of secondary leaves began, thereby multiplying the number of growing points. From this time on the greater part of the increase in leaf area took place in the secondary leaves. By far the most rapid period of leaf growth occurred at about the time when squares first began to form. In Series I the average total leaf area practically doubled every ten days through the seven weeks under observation. In Series II the plants were older to start with, and it required about forty days to double the leaf area.

Everyone now concedes that it is useless to attempt the spraying of full-grown cotton such as is represented in Series II. The extreme rapidity of increase in the foliage area shown in the first part of Series I shows that spraying must be repeated every week or ten days if even one-half of the entire leaf area is to be kept poisoned. When in connection with the large per cent of daily increase we consider how much of that percentage is being unfolded at the very tip of the stem; that upon that limited tip area alone will the weevil feed before the formation of squares; that after the formation of squares it appears to be absolutely impossible to poison the weevil's food supply, and also that the irregular emergence of the weevils from hibernation may extend through several weeks, it at once becomes evident that spraying early cotton for hibernated weevils is almost as impracticable as the spraying of older cotton is now acknowledged to be.

EFFECTS OF FEEDING UPON SQUARES AND BOLLS.

From numerous large, open, feeding punctures a square becomes so severely injured that it flares very quickly, often within 24 hours. Males usually make the largest punctures, and always leave them open while they remain for a day or more working upon the same square. It has been often found that squares thus injured by a male will flare before the weevil leaves it. The time of flaring depends upon the degree of injury relative to the size of the square. Thus, small squares receiving only a single large feeding puncture in the evening are found widely flared in the morning. On the other hand, large squares which are within a few days of the time of their blooming may receive a number of punctures without showing any noticeable flaring. Frequently a square which has flared widely will be found later to have closed again and to have formed a distorted bloom (Pl. VI, fig. 30; Pl. VII, fig. 31), and occasionally such squares develop into normal bolls. In squares of medium size a single feeding puncture does not usually destroy the square. The destruction of a square by feeding results either from drying, decay, or a softened, pulpy condition of the interior which is the consequence of the weevil injury.

Bolls are quite largely fed upon after infestation has reached its height. Small and tender bolls are often thoroughly riddled by the numerous punctures (Pl. VII, fig. 32). Small bolls so severely injured fall within a short time. Larger bolls may receive more punctures without being so severely injured. A comparison of the external and internal effects in such cases is shown in Pl. VIII, figs. 34, 35. Abnormal woody growth takes the place of the normal development of the fiber, and a softening and decay of the seeds often accompanies this change. One or more locks may be destroyed while the remainder of the boll develops in perfect condition (Pl. VII, fig. 33; Pl. X, fig. 38).

After the bolls become about half grown the effects of feeding are less liable to cause the boll to fall (Pl. I, fig. 10). The puncture becomes closed by a free exudation of the sap and a subsequent woody growth, which forms frequently an excrescence the size of half a pea upon the inner side of the carpel. An excrescence of this character usually results from an egg puncture, and often from feeding punctures.

DESTRUCTIVE POWER BY FEEDING.

A glance at the figures in Table VIII (p. 40) is sufficient to show the great destructive power of the Mexican cotton boll weevil. It may be seen that both in the field and in the laboratory the weevils of the first generation are more active in making punctures than are the hibernated weevils. These generations overlap too far to attribute this difference to the influence of a higher temperature alone, though this factor will account for a large part of it. A comparison of the figures for males alone with those for females alone or with those for males and females together shows that it is very conservative to say that males make less than half as many punctures as do females. By the habit of distributing their punctures among a greater number of squares the destructiveness of the females becomes at least five times as great as that of the males.

This great capacity for destruction has been one of the most evident points in the history of the spread of the weevil, and deeply impressed the entomologists who first studied the insect in Texas. In 1895 Mr. E. A. Schwarz, in writing of the work of the weevil at Beeville, said:

> Each individual specimen possesses an enormous destructive power and is able to destroy hundreds of squares, most of them by simply sticking its beak into them for feeding purposes.

SUSCEPTIBILITY OF VARIOUS COTTONS.

An excellent opportunity for observations upon this point was obtained upon the laboratory grounds at Victoria by growing within a small area plants of several varieties of American Upland, Sea Island, Egyptian (Mit Afifi), Peruvian, and Cuban cotton (*Algodon sylvestre*). The Peruvian cotton made a remarkably large growth, but put out no squares, so that it does not really enter into this comparison. The Mit Afifi seed was obtained through the courtesy of the Bureau of Plant Industry of this Department from a field grown the preceding season at San Antonio, Tex., in which circumstances led some observers to the opinion that the variety was, to a certain extent, immune. The observations at the laboratory were made by carefully examining the plants, looking into each square, and removing every weevil and infested square found. If there were any distasteful or resistant cotton among these, it would surely be found in this way; and if any variety were especially attractive to the weevils it would be equally apparent. Infested squares being removed, the accident of association or proximity would not determine the location of the weevils found, but all might be considered as having come to the cotton with equal opportunities to make their choice of food, and accordingly their location has been considered as indicating such choice. The period of observation extends from June to November, except with the Cuban cotton, which was planted late and began to square during the latter part of August. For the purpose of this comparison, both the varieties and the several plots of the American cotton will be considered together, as no evidence of preference was found among them.

In making a comparison of the results three elements must be considered for each variety of cotton: First, the number of plants of each variety; second, the number of days during which each kind was under observation; third, the total number of weevils found on each class of cotton. The elements of numbers of plants and times of observation may be expressed by the product of those two factors forming a term which we may call "plant-days." The total number of weevils found upon any class of cotton divided by the number of "plant-days" will give the average number of weevils attracted by each plant for each day, and these numbers furnish a means of direct comparison and show at a glance the average relative attractiveness of each class of cotton. The following table presents these results in comparable form:

TABLE X.—*Relative attractiveness of various cottons.*

Class of cotton.	Number of plants.	Total.			Average.		Relative attractiveness.
		Plant days.	Weevils found.	Infested squares.	Weevils per plant per day.	Infested squares per weevil.	
American	62	4,920	287	3,507	0.058+	12.2+	1.0
Cuban	5	120	11	136	.092−	12.4−	1.6+
Sea Island	8	552	64	1,089	.116−	17.0+	2.0
Egyptian	8	808	207	2,013	.256+	9.7+	4.4+
Total of 3 non-American cottons	21	1,480	282	3,238	.191−	11.5−	3.3−

An examination of these figures shows that American Upland cotton is less subject to the attacks of the weevil than any of the others, and that Egyptian (Mit Afifi) is by far the most susceptible. The difference in degree is most plainly shown in the column of "relative attractiveness." It would certainly seem difficult to formulate a stronger argument for the cultivation of American cottons alone within the weevil-infested district than is presented by these figures. The weevils gathered so thickly upon the Egyptian cotton that the plants could not produce sufficient squares to keep ahead of the injury, and therefore the average number of infested squares for each weevil is only three-fourths as great with that variety as with less infested kinds, but the average injury to each square was greater than with any other.

The practical application of these observations may be emphasized still further by the statement that in spite of the frequent and careful removal of weevils from these cottons during the entire season none of the non-American varieties made a single boll of good cotton, so great was the actual weevil injury to them, while American cotton with the same treatment developed a large number of bolls.

The results are still further sustained by observations upon larger areas of American and Egyptian cotton under field conditions in three localities in Texas, no weevils being removed from either kind. At Victoria, Tex., on August 26, 1903, an examination showed that 96 per cent of Egyptian squares were infested, while an average of 13 fields of American showed 75.5 per cent. At Calvert, Tex., on September 4, Egyptian showed 100 per cent infested, while the American varieties growing alongside showed 91 per cent. Similar results were found at San Antonio. Though growing in close proximity, the Egyptian produced no staple whatever, while the American gave better than an average yield in spite of the depredations of the weevil.

In accordance with these observations, it appears that in developing a variety of cotton which shall be less susceptible to weevil attack by far the most promising field for work lies among the American varieties, and of these the very early maturing kinds are most promising.

The question of choice of different varieties for food was tested in the laboratory by Dr. A. W. Morrill, by placing squares of two kinds of cotton, American and Egyptian, in alternate rows in a breeding cage (Pl. XII, fig. 48), so lettered and numbered that each square could be exactly located. Weevils were then placed so that they could take their choice of these squares, and observations from 8 a. m. to 6 p. m. were made upon the location and activity of the weevils. Though this experiment was repeated four times, no positive evidence was obtained to show that weevils had any choice as to which kind of squares they fed upon. Table XI presents a summary of these results.

TABLE XI.—*Breeding-cage observations upon weevil choice of American and Egyptian squares.*

Experiment.	Period of observation.	Number of observations.	Weevils used.	American squares.				Egyptian squares.			
				Total number.	Infested.	Feeding punctures.	Egg punctures.	Total number.	Infested.	Feeding punctures.	Egg punctures.
1	12 m. to 8 a. m	8	10	16	12	15	5	16	5	12	3
2	11.45 a. m. to 9.45 a. m	5	10	16	5	19	1	16	5	13	3
3	12 m. to 5 p.m. day after	5	10	16	7	25	2	16	9	27	2
4	11.45 a. m. to 9 a. m	5	10	16	6	17	6	16	8	14	3
5	6 p. m. to 8 a. m	1	18	4	2	7	0	4	2	10	0
	Total	24	58	68	32	83	14	68	29	76	11

In experiments 1 and 2 the American squares were attacked more extensively than were the Egyptian, while in experiments 3 and 5 greater injury was done to the Egyptian. In experiment 4 the smaller number of egg and feeding punctures made in the Egyptian squares is counterbalanced by the larger number of squares attacked. Although the totals from these five tests show slightly less injury to the Egyptian than to the American squares, it could hardly be expected that two arbitrarily chosen series, even if of the same variety, would show any closer agreement in the points of comparison made in this table than is therein shown by the American and Egyptian squares.

HAS THE WEEVIL ANY OTHER FOOD PLANT THAN COTTON?

The question of the possibility of boll weevils feeding upon some other plant than cotton is one of great importance. It is a well-known fact that insects which have few food plants usually confine their attacks to closely related plants belonging to the same botanical family, or even genus. Accordingly, most of the plants which have been tested especially are most closely related to cotton. Four species of Hibiscus (*H. esculentus*, *H. vesicarius*, *H. manihot*, *H. moscheutos*) were grown and an effort made to see whether weevils would feed upon either the leaves, buds, or seed pods. In no case, however, did they live on any of these for any considerable time, though they fed slightly upon some of the parts. Hibernated weevils starved in an average time of about 4 days with leaves of either okra or Sunset Hibiscus. The buds and seed pods were not formed at that time, so could not be tested. Weevils of the first generation, which had had no cotton for food, were placed upon Sunset Hibiscus, and these starved in an average of 3 or 4 days. First generation weevils, which had fed for a few days on squares, were placed upon leaves, buds, and seed pods of *Hibiscus vesicarius*. Though they fed a little, all starved in an average of about 5 days. A lot of first generation weevils, fed first for several days with squares, were given leaves, buds, and seed pods of okra. More feeding was done by this lot than by any other, all parts being slightly attacked. These weevils lived for an average of 7 days.

Numerous other plants, including sunflower (*Helianthus annuus*), bindweed (*Convolvulus repens*), the slender pigweed and the spiny pigweed (*Amaranthus hybridus* and *A. spinosus*), and western ragweed (*Ambrosia psilostachya*), and various other species of weeds and grasses which occur more or less frequently around cotton fields were tested, but in no case was feeding noticed except in the case of weevils supplied with pieces of the stem of sorghum, the stems of which were cut into short lengths and some of the pieces split lengthwise. Upon the exposed, juicy pith weevils fed considerably, but they did not puncture through the hard stem to obtain the juice. The sweet sap found in the pith sustained weevils for some time in the laboratory, but where obliged to puncture the stem, as they would be in the field, they would never attack sorghum, except possibly freshly cut stubble. Among the many plants tried, therefore, none has been found to show any capacity for sustaining the lives of weevils in the field in the absence of cotton.

The question of the original food plant of the weevil has received considerable attention from this Division, the investigations made in Cuba being particularly thorough and conclusive. In that island some varieties of cotton grow wild and are perennial. After most careful search Mr. E. A. Schwarz wrote in the spring of 1903: "There is not the slightest doubt, in my opinion, that the original and only food plants of the weevil are the varieties of Gossypium and here in Cuba the variety known as kidney cotton." The investigations of the Division of Entomology have given special attention to the possibility of the boll weevil breeding on other plants than cotton. Throughout the investigations of Prof. C. H. T. Townsend in southern Texas and in Mexico and the careful studies made by Mr. Schwarz in Texas and in Cuba and the observations made by the writers in Texas every plant closely related to cotton has been most carefully watched, and the uniform failure to find the weevil upon any other plant makes it practically certain that cotton is its only food.

INSECTS OFTEN MISTAKEN FOR THE BOLL WEEVIL.

Many species of insects have been mistaken for the Mexican cotton boll weevil. Among them the two most commonly reported in Texas have been an acorn weevil (Pl. XIV, fig. 55) and a species commonly found upon bloodweed or ragweed. The chief reason for the prominence of these two species is not that they resemble the boll weevil more closely than do others, but rather that their habits bring them into closer proximity with cotton fields and their abundance has led to their more frequent discovery. The acorn weevil has in a number of cases been taken in lantern traps set in cotton fields, and the mistake in the proper identification of the species has given currency to the report that the boll weevils are attracted to lights, which, however, is never the case. There is no authentic record of a single boll weevil having been caught at any light. Only very rarely and under exceptional conditions will the acorn weevil feed at all upon cotton bolls.

Though the bloodweed weevil (Pl. XIV, fig. 54) has been taken from cotton plants, no evidence has been submitted showing that it was actually feeding thereon, and it is more likely that such specimens had merely strayed to the cotton from bloodweed growing near.

Another species of weevil, *Desmoris scapalis* (Pl. XIV, fig. 58), is much less common and therefore less frequently mistaken, but resembles the boll weevil in general appearance far more closely than does

FIG. 29.—SQUARES MUCH FED UPON, NATURAL SIZE. (ORIGINAL.)

FIG. 30.—DISTORTED BLOOM, CAUSED BY FEEDING UPON LARGE SQUARE, NATURAL SIZE. (ORIGINAL.)

FEEDING INJURIES ON BLOOMS AND BOLLS.

Fig. 31, Blooms distorted by feeding punctures, open but imperfect, two-thirds natural size; fig. 32, small boll riddled by feeding punctures, natural size; fig. 33, one lock of boll destroyed by feeding punctures, two-thirds natural size. (Original.)

either of the species previously mentioned. This insect has been found attacking white prickly poppy (*Argemone alba*) and tumbleweed (*Amaranthus græcizans*) in the spring, and probably breeds on *Prionopsis ciliata* Nutt and the broad-leaved gum plant (*Grindelia squarrosa*).

In general the food habits of any species are among its distinctive, specific characters, and as the structural differences are easily overlooked and difficult of appreciation by anyone unacquainted with the careful study of insects, a rather full, though by no means complete, list is here given of the species which have been reported to the Division of Entomology as having been confused with the boll weevil.[a] Many of the most common species will be found figured among the illustrations. The scientific names of the insects are given because they are definite and refer positively to a single species, whereas the common names are used so loosely that the same name may be applied to a number of species having possibly similar habits. The boll weevil is included in this list, and figures of the adult are given in the plates to facilitate comparison. In many cases no common name has yet been given to the species. Seven of the species mentioned attack living cotton and five species are found feeding only in decaying bolls. The occurrence of the remainder upon cotton is merely incidental.

Insects often mistaken for the boll weevil.

Scientific name.	Common name.	Usual food plant.	Plate figure.
WEEVILS.			
Anthonomus grandis Boh	Mexican cotton boll weevil	Cotton squares and bolls.	XIV, 52, 53.
Anthonomus albopilosus Dietz.			
Anthonomus prunicida	Plum gouger	Plums	XIV, 57.
Balaninus uniformis auct	Acorn weevil	Acorns	XIV, 55.
Centrinus penicellus Hbst		Beetle in flowers	XV, 61.
Centrinus picumnus Hbst		do	
Chalcodermus æneus Boh	Cowpea-pod weevil	Cowpea pods	XV, 63, 64.
Desmoris scapatis Lec		Broad-leaved gum plant	XIV, 58.
Desmoris constrictus Say			
Dorytomus mucidus Lec		Willow	
Lixus læsicollis Lec	Blood-weed weevil	Ragweed (*Ambrosia* spp)	XIV, 54.
Coccotorus scutellaris	Apple curculio	Apple	XIV, 56.
Baris striata Say	Striped Baris	Stems of ragweed	
Baris transversa Say	Transverse Baris	Roots of cocklebur	XV, 59, 60.
Anthribus cornutus Say	Horned stem borer	Cotton stems	
Aræcerus fasciculatus DeG	Coffee-bean weevil	Coffee beans and old cotton bolls.	XV, 62.
Epicærus imbricatus Say	Imbricated snout beetle	Omnivorous	XVI, 69.
Hylobius pales Hbst			
Rhynchites mexicanus Gyll	Mexican rose beetle	Beetles attack rose	
Tychius sordidus Lec		Common in cotton fields	
Ophryastes bituberosus Shp		Found on cotton	
Trichobaris mucorea Lec	Tobacco-stalk weevil	Tobacco stalks	

[a] In the preparation of this list we are under obligations for assistance to Mr. F. H. Chittenden, who has also furnished information in regard to the food habits of the species.

Insects often mistaken for the boll weevil—Continued.

Scientific name.	Common name.	Usual food plant.	Plate figure.
OTHER BEETLES.			
Monocrepidius vespertinus Fab.		Larva in grass roots	XVI, 70.
Notoxus monodon Fab.		Larva in ground	
Ataxia crypta Say	Cotton-stalk borer	Cotton stalks	XVI, 68.
Olibrus apicalis Mels.		Decaying bolls	
Carpophilus hemipterus Linn.		Develops in decaying bolls	
Carpophilus dimidiatus Fab.		do	
Epuræa æstiva Linn.		do	
Cathartus gemellatus Duv.	Grain beetle	do	
Tribolium ferrugineum Fab.	Flour beetle	Attacks seed	
BUGS AND OTHER INSECTS.			
Homalodisca triquetra Fab.	Sharpshooter	Cotton stalks	XVI, 65, 66.
Oncometopia undata Fab.	Waved sharpshooter	do	
Dysdercus suturellus H-Sch.	Cotton stainer	Cotton bolls	XVI, 67.

IS COTTON-SEED MEAL ATTRACTIVE?

LABORATORY OBSERVATIONS.

On account of the popular impression that cotton-seed meal will attract weevils it has been necessary to conduct a rather full series of experiments. To ascertain the possibility of using this substance as an attractant for the weevil in field work three series of laboratory tests were first made. The weevils used were obtained from the same source in all tests. The first series was designed to test the ability of the weevils to live upon cotton-seed meal alone as a food. The second series was intended to show whether the weevils would prefer the meal to cotton leaves as an indication of the possibility of attracting hibernated weevils before the formation of squares in the spring. The third series was planned to show whether the weevils would prefer the meal as a food when squares could be easily found. The cotton-seed meal used was obtained fresh from the oil mill and the experiments started during the latter part of November.

Weevils fed rather sparingly upon the meal in Series I. It did not seem to agree with them as a food and they showed no special inclination to feed upon it. Twenty-three of the 24 weevils confined upon meal alone died in from 2 to 13 days, showing an average length of life of slightly over 6 days. These weevils either starved to death rather than eat the cotton-seed meal or else they were not able to eat it. The dry and empty bodies of all dead weevils showed that death was caused by starvation and not by disease. Being entirely covered with the fine meal did not seem to have any bad effect upon them. As weevils without food or water showed an average length of life slightly over 6 days, agreeing exactly with the period in this test, it appears that cotton-seed meal is not only not a food for the weevil, but also that it is not capable of prolonging their lives to any appreciable extent.

In Series II 21 weevils were confined with fresh cotton leaves and cotton-seed meal as food. During the 297 "weevil-days" that this experiment was continued but one weevil died. The average period of the test for each weevil was 14 days. The weevils fed almost wholly upon leaves. Occasionally one would feed a little on the meal, but they certainly preferred the leaves, and the results show that leaves alone were responsible for the longer life of these weevils. The 20 survivors were placed in hibernation December 20, 1902, but all died before April 15, 1903.

In Series III freshly picked squares were placed with the meal to see which would attract the weevils. Fresh meal, as well as squares, was supplied at frequent intervals. During the 158 "weevil-days" that this test continued not one of the 10 weevils died. The average period of the test was almost 16 days, and after it the weevils were placed in hibernation, but all died before April 15, 1903. In only one instance was a weevil observed feeding upon the meal. From this test it was evident that cotton-seed meal has not the power to attract weevils from squares, even when the latter have been picked for several days.

In spite of the complete failure indicated by these results, a series of field tests was made during the late fall of 1902.

FIELD TESTS.

In order to settle this question finally, two series of field tests were made, one during the fall, when weevils were abundant but full-fed and cotton still standing, and the other during the early spring, with the view of attracting weevils as they came from hibernation before cotton began to square.

Fall of 1902.—Cotton-seed meal fresh from the mill was placed in 10 cheese-cloth bags, which were shaken so that the fine dust from the meal covered the outside of each bag. The bags were numbered and then tied to cotton plants in infested fields at about the middle of the plants. The bags were so distributed as to test fields in which the following conditions prevailed: One field entirely black from frost, one nearly black, one about half green, and one still entirely green. The number of weevils on the plant to which the bag was attached was noted each day to ascertain in a general way the number of weevils which would be very near the meal and able to reach it in the ordinary course of travel over the plant without having to fly to it. Weevils on adjacent plants would naturally come within the sphere of influence if such existed, but they were disregarded. After the failure of the meal to attract weevils in the field became apparent, weevils were caught and placed upon the bags to see if they would stay there.

Altogether 65 observations were made, covering a period from November 24 to December 16. The weather was generally cool, averaging about 61° F., mean temperature, and cotton had ceased to grow. Counting each weevil found at each observation, only 5 were found upon the 10 bags of meal. Of these 5, 3 were hidden in the folds of the cloth for shelter and were not feeding. One weevil was counted twice and was the only one found that appeared to be feeding upon the meal. During this period a total of 163 weevils was found upon the top parts of the plants to which the bags were attached. This is considerably below the real number present, because in many instances this examination was not made, and doubtless weevils were overlooked even when examination was made.

At various times 27 weevils were placed directly upon the bags of meal and given every opportunity to show whether they would stay thereon if they accidentally found the meal. Only one of this number stayed upon the bag for 24 hours, and this one remained in the shelter of the cloth.

The unattractiveness of cotton-seed meal for the weevils seems absolutely proven so far as fall conditions are concerned.

Spring of 1903.—These tests were intended to show whether hibernated weevils would be attracted to the meal before squares were to be found in the field. Two series of experiments were planned, using four bags of meal in each. For the location of the first series a field was chosen which was known to have been badly infested with weevils up to December 18, 1902. This field was not replanted with cotton in 1903, nor was there another field in the vicinity, so that weevils coming from hibernation would find no possible food except the meal. A number of live hibernated weevils was taken from this field, so that there can be no doubt of the presence of many of them. The bags of meal were placed near apparently favorable hibernating places.

Fifty-five observations were made under these conditions, but not a weevil came to the bags of meal.

For the second series a field was selected in which occasional seppa cotton plants were found. The plants had been allowed to stand through the winter in this field, and hibernated weevils were quite abundant. The bags of meal were here attached to stakes driven beside seppa plants. More than 50 observations were made after weevils were known to be out of their winter quarters. Nine weevils were found upon the seppa cotton plants beside which the bags of meal were placed, but not a weevil was found on the meal.

Only one conclusion can be drawn from these experiments. Under no conditions will cotton-seed meal serve as a food for the weevils, and it shows no power whatever of attracting them.

THE POSSIBILITY OF BAITING WEEVILS WITH SWEETS.

ATTRACTIVENESS OF VARIOUS SWEETS.

On account of the considerable publicity given the theory that it might be possible to destroy the weevil by attracting it to sweetened poisons, a number of experiments were performed along this line.

In the course of this work Mr. G. H. Harris employed in the laboratory tests a large variety of sweets. White granulated sugar, two or three grades of brown sugar, two or three grades of molasses, and the best strained honey were among the sweets tried. The conditions were such as to lead the weevils to eat the sweets if they would ever do so. The only alternative offered them for food was a supply of rather old cotton leaves such as weevils never touch in the field. In spite of the unfavorable conditions for getting at the real choice of the weevils they showed little inclination to feed upon the sweets except in the case of honey, which seemed to attract them quite strongly. Many weevils fed upon the unattractive leaf tissue or upon the broken end of the petiole rather than upon the sweets.

The result of Mr. Harris's experiments with undiluted molasses applied to plants in the field as summed up in his own words was that "nothing indicated that the weevils were attracted by the odor of sweets." Honey was then tried, and this did attract a few weevils. Mr. Harris's general conclusion, based upon the results of his experiments, was that "while a high grade of sweets seemed to have more attraction than a cheaper grade, neither can be depended upon to attract the weevils for poisoning."

ATTRACTIVENESS OF SWEETS TO HIBERNATED WEEVILS IN LABORATORY.

The sweets used in these tests were of three kinds: High-grade molasses, common molasses, and light-brown sugar. The weevils were brought in from the field and left for one week without food or drink previous to the beginning of the tests on April 2, 1903. Three weevils were used with each kind of sweet, the latter being in their strongest form and the sugar in a saturated solution. The inclosing apparatus was formed by placing two bottles mouth to mouth with sufficient space for air, but not enough for the escape of the weevils between them. In the bottom of one bottle was placed the sweet and the second leaves of cotton in the bottom of the other. The weevils were then inclosed, and the cages thus formed were placed in a horizontal position in the dark to eliminate every possible influence of direction of light, relative elevation of food, etc. The food supplies were renewed occasionally, and the location of the weevils relative to the food in each cage was noted frequently. The weevils were counted at each observation. The results of these observations are briefly summarized in the following table:

Table XII.—*Attraction of various sweets vs. cotton, second leaves.*

Character of sweet.	Number of observations.	Number of weevils on cotton.	Number of weevils at sweets.
Best molasses, cage 1	20	25	1
Best molasses, cage 2	13	29	5
Common molasses, cage 3	18	42	4
Brown-sugar sirup, cage 4	21	48	8
Total	72	144	18

These figures become even more striking in consideration of the fact that the cotton leaves were often purposely left until they became moldy and decayed or dried and wholly unfit for food. It was at such times that most of the weevils sought the sweet in preference. Should we leave out of the account the weevils found at the molasses or sirup when the cotton was unfit for food, the number attracted there would be reduced fully one-half. In either case the fact remains that none of the sweets can be said to have attracted weevils from the cotton leaves.

INFLUENCE OF SWEETENED WATER UPON FEEDING OF WEEVILS ON COTTON PLANTS.

It is easy to demonstrate that weevils will in confinement feed upon sweet solutions. To prove that they will show the same attraction to it in the field is a far more difficult matter.

For the purpose of these experiments, cheap molasses was used, mixing 1 part of molasses with 25 parts of water, as is generally recommended in spraying formulæ. Three pairs of young plants which had not begun to square were then selected from those growing upon the laboratory grounds. The plants in each pair were of equal size, and both in healthy condition and standing closely enough together to be both covered by one cage. One plant of each pair was then dipped in the sweetened water, while the other was left in its natural condition. In each of the cages 10 weevils were then placed upon the ground and midway between the bases of the plants. The object of the test was to see which plant, the treated or untreated, would attract the larger number of weevils. During the first three days observations were made several times each day. Weevils found upon either plant were counted at each observation.

A summary of the observations made on the first day before the liquid had dried showed 15 weevils upon the sweetened plants and 16 on those not sweetened. These results were so remarkably even that no attraction or repulsion could be ascribed to the liquid before it dried.

During the ten days covered by the observations, however, 63 weevils were found upon the unsweetened plants and only 45 upon those sweetened. The weevils fed largely upon the petioles and somewhat upon the blades of the leaves and the main stems of the plants. No indication was observed of special feeding upon the "gloss" left by the drying of the sweetened water. In each cage the normal untreated plant was destroyed before the treated one. During the first half of the observations 52 weevils were found feeding upon the unsweetened plants and only 32 upon the sweetened. Only after every leaf on the untreated plants hung black and dead, while the sweetened plants were in much better condition, did more weevils attack the sweetened plants.

Not only did these tests show that molasses in solution has no attraction for the weevils, but also that the sticky coating left after the liquid has dried acts more as a positive repellant to them.

FIELD TESTS FOR HIBERNATED WEEVILS, USING PURE MOLASSES.

As a final experiment to settle the possible usefulness of molasses in the weevil fight, a large series of tests was undertaken in the field to see if the pure, undiluted molasses would not prove attractive to weevils as they came from hibernation. To insure a continuous supply of fresh molasses a test tube was nearly filled and then rather tightly plugged with a small stopper wound with cotton. The tube was then fastened in an inverted position to the top of a stake about 2 feet long, and as the molasses gradually oozed through the cotton it ran slowly down the stake, forming a streak of continuously fresh molasses a foot or more in length. The supply would thus last for several days and was then easily replenished. This apparatus, as shown in Pl. XII, fig. 45, was then placed beside a vigorous seppa cotton plant in the field at the season when the weevils were beginning to leave their winter quarters and seek food to break their long fast. Both high and low grades of molasses were employed in these tests, three tubes of each being used. Altogether 84 observations were made between April 24 and May 15, 1903, during which period most of the weevils emerged from hibernation.

The results again proved disappointing, for only a single weevil was ever found at the molasses. This individual sipped occasionally at the sweet, wandering up and down the tube in the intervals. It did not appear to be satisfied and did not remain long at or near the molasses, but flew away and was not found there again.

The failure of the molasses to attract was not due to the scarcity of weevils in the field. During the period of observation 23 weevils were found working upon seppa cotton very near the molasses tubes, and certainly within reach of its attractive influence, provided it had any. More weevils were also found in the same field, but at somewhat greater distances from the tubes.

During the warm days toward the close of the experiment many butterflies, mostly *Vanessa atalanta* and some *Anosia plexippus*, came to the tubes. A few specimens representing several species of beetles and many ants were also found.

None of the experiments made, either in the laboratory or in the field at Victoria, Tex., has shown that weevils are attracted in even the slightest degree to any grade of molasses, either in its undiluted or diluted form. No sugar solution has been found to possess any more attraction than does molasses. Honey appears to be an especially attractive sweet, but is too expensive for use in this manner.

Considering the facts that these experiments have been much more numerous and that they have covered a much broader range of conditions than any previously performed, we must conclude that it yet remains to be shown that sweets of any kind have any value in the problem of controlling the boll weevil.

FEIGNING DEATH.

This interesting habit of the weevil is its first resort as a means of escape from its larger enemies. It has been the basis of many machines designed to jar them from the plants and to collect them in convenient receptacles. If jarred from the plant, the weevil falls to the ground, with its legs drawn up closely against the body and the antennæ retracted against the snout, which is brought inward toward the legs. The position is characteristic and can be more easily shown than described. See Pl. I, fig. 2. In this position it often remains motionless for some time. If further disturbed, so that it finds that its ruse has failed to conceal it, it will start up quickly, run a little way, and again fall over, feigning death. The color of the weevil so closely resembles that of the ground that it is quite difficult to find a fallen individual so long as it remains quiet. The habit is of great value in protection. If left undisturbed until it believes danger to be past, it recovers its footing and returns to the plant.

REPRODUCTION.

Under this general heading we present some of the most interesting observations which have been made upon the habits of the boll weevil. The relation of the sexes, the evident selection of clean squares for egg deposition, the great destructive power of the weevil, the rapidity of development, and the influence of varying temperatures upon its activity and development may also be classed as among the most important as well as most interesting observations.

METHOD OF MAKING FIELD OBSERVATIONS UPON WORK OF WEEVIL.

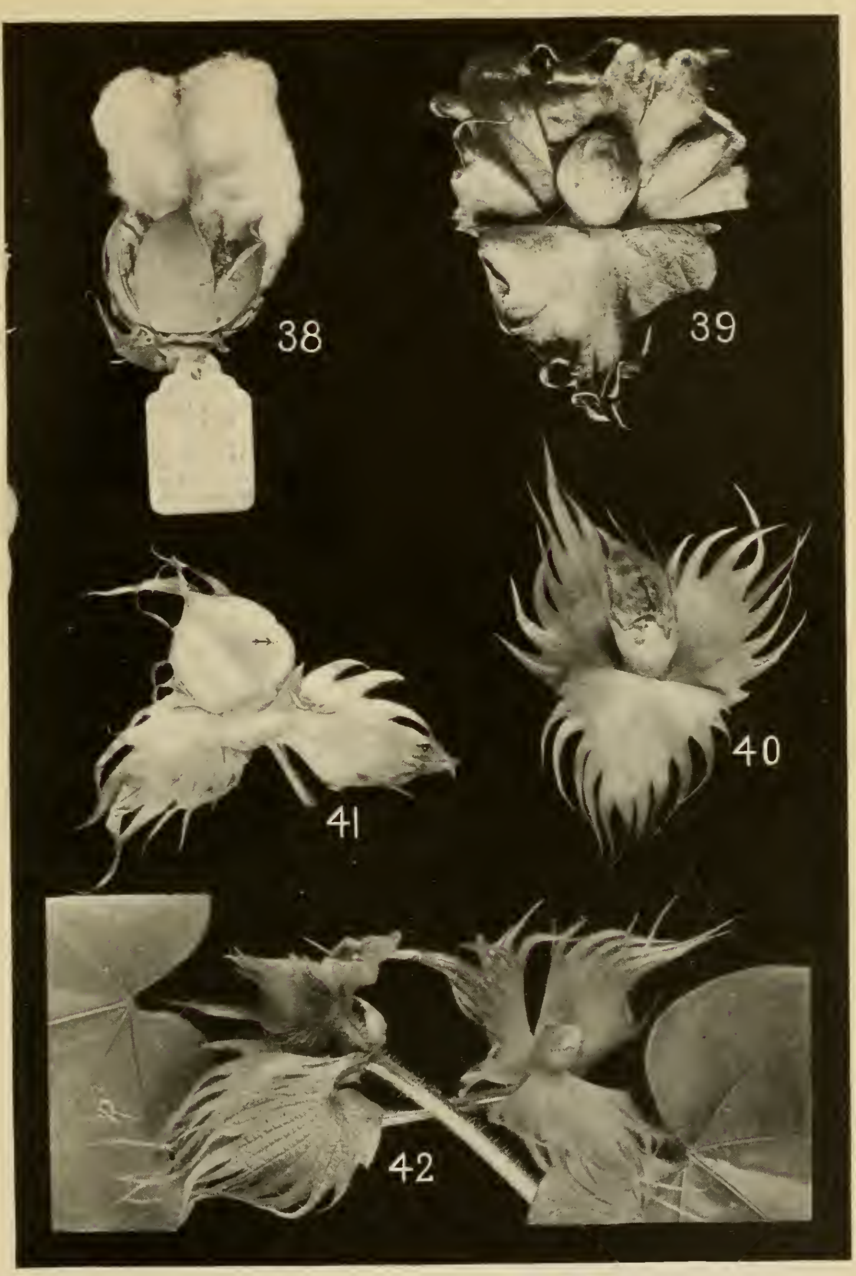
For the purpose of field study large cages (3 by 3 by 4 feet) were made, the covering being of fine wire screening (Pl. IX, fig. 36). Uninfested plants having plenty of squares were found by a careful examination of each square and inclosed by the cages. The number of weevils placed in each cage was varied according to the number of squares within, ranging from 2 to 5 at various times. In making the daily observations the cage was entered and each square examined. Each square found attacked in any way was marked with a numbered tag containing full data as to the lot of weevils and the number present, date, and nature of injury (Pl. IX, fig. 37). After all weevils had been found the cages were removed to new uninfested plants for another day's work. Close watch was kept upon all tagged squares upon succeeding days, and every important change taking place in each square was added to the record on the tag. The special points

EXTERNAL AND INTERNAL INJURY FROM FEEDING ON BOLLS.

Fig. 34, External appearance of large boll much fed upon, natural size; fig. 35, internal appearance of same boll, natural size. (Original.)

FIG. 36.—CAGES USED TO CONFINE WEEVILS IN FIELD. (ORIGINAL).

FIG. 37.—PLANT SHOWING TAGGED SQUARES FROM CAGE WORK. (ORIGINAL.)



EGG AND FEEDING PUNCTURES: EFFECTS ON SQUARES AND BOLLS.

Fig. 38, Boll showing two locks destroyed by two feeding punctures made by a male weevil, two-thirds natural size; fig. 39, square showing external appearance of two egg punctures, natural size; fig. 40, wart formed on side of square in healing an egg puncture, natural size; fig. 41, egg deposited on inside of carpel of a boll, two-thirds natural size; fig. 42, normal and flared squares, natural size. (Original.)

noted in each case, so far as was possible, were: The formation of a distinct wart; time of flaring, yellowing, and falling; the emergence of adult; presence of a parasite; death of larva, pupa, etc. A very complete history of each square was thus obtained. During the season of 1903 three special periods were selected for study of this kind. The first was taken during the early part of June, when hibernated weevils only were active, the second was taken in August for the work in midsummer, and the third in the latter part of October for the study of the development of late weevils. Altogether in these three series over a thousand squares were tagged and recorded. The work of males was compared with that of females in this way, as were also the developmental periods in squares and bolls. Although requiring a great deal of time and close attention, the numerous definite observations obtained abundantly justified the work required.

FERTILIZATION.

AGE OF BEGINNING COPULATION.

After the adult weevils have left the squares a certain period of feeding is necessary before they arrive at full sexual maturity. This period varies in length according to the effective temperature prevailing and appears to bear about the same ratio to the developmental period as does the pupal stage.

Among the many weevils kept from emergence till death for the purpose of ascertaining the length of life without food, copulation was never observed. With weevils fed upon leaves alone the period preceding copulation is about twice the normal length in the cases observed of those having squares to feed upon.

During the hot weather this period appears to be on the average only about three or four days in length, while as the weather becomes colder it increases gradually until weevils may become adult, feed for a time, and go into hibernation without having mated. A single union seems to insure the fertility of as many eggs as the average female will lay, and its potency certainly lasts for a period fully equal to the average length of life.

SEXUAL ATTRACTION AND DURATION OF COPULATION.

The distance through which the attraction of the female will influence the male varies extremely. To ascertain how far the attraction might be exerted in the case of the boll weevil, 2 females were confined with food in a small bottle covered with cheese cloth, and the bottle was then placed in a horizontal position inside a field cage and near its top. Within this cage were 3 males which had been confined there alone for 4 weeks. The bottle containing the females was so placed as to be within a few inches of the top of a cotton plant upon which the males were working and touching the leaves of the plant, in order to afford the males access to the bottle without having to fly to it.

Close watch was kept, but during 11 days not a male was seen to go near the bottle. At the end of that time the females were taken into the laboratory, as was also one of the males from the cage. All were removed from squares and, being placed upon the table, were brought gradually nearer together. The male paid no attention whatever to the nearest female until brought within an inch of her. He then went directly to her. The sense of smell appeared to guide his movements. The fact that this male mated readily with both of the females used in the cage shows that the only reason for failure to attract in the cage lay in too great distance separating the sexes.

These observations are entirely borne out by those made in the field. The fact appears to be that the sexes are attracted only when they meet either on the stems or upon the squares of a plant. The comparative inactivity of the male has a bearing on this matter. The general conclusion is that instead of seeking widely for the females, the males are content to wait for them to come their way. The greater comparative activity of females is shown in the study of their food habits.

In a number of cases that were timed the average duration of the sexual act was very nearly thirty minutes.

DURATION OF FERTILITY IN ISOLATED FEMALES.

A number of females which were known to have mated were isolated to determine this point. Although neither limit was exactly determined, the results proved very striking. Several of these females laid over 225 eggs each and nearly all of them proved fertile. Selecting three cases in which the facts are positively known, it appears that fertility lasted for an average of something over 66 days and that during this period these females deposited an average of nearly 200 eggs. The maximum limits may possibly be considerably higher than these.

OVIPOSITION.

AGE OF BEGINNING OVIPOSITION.

Normal oviposition seems never to take place until after fertilization has been accomplished, but it usually begins soon after that. Observations upon the age at which the first eggs are deposited can be made more easily and more positively than those upon the age at which fertilization takes place. In a general way, therefore, the observations here given may be considered as also throwing light upon the time of beginning copulation.

In the breeding of weevils from eggs deposited by hibernated females a number of observations accumulated upon this point and another series was made in the fall of 1902. The results of both series are given in Table XIII.

TABLE XIII.—*Age of beginning oviposition.*

WEEVILS OF FIRST GENERATION, 1903.

Date adult.	Date of first egg.	Number of females.	Elapsed time.	Weevil days.
1903.	1903.		*Days.*	
June 8 to 9	June 17 to 18	3	9.0	27.0
June 10	June 19	1	9.0	9.0
June 11	June 16	7	5.0	35.0
June 12	do	1	4.0	4.0
Do	June 19	2	7.0	14.0
June 13	June 18	4	5.0	20.0
June 13 to 14	do	5	5.0	25.0
June 14	do	4	4.0	16.0
Total		27		150.0
Average time after adult				5.5+

WEEVILS BRED IN FALL OF 1902.

Date adult.	Date of first egg.	Number of females.	Elapsed time.	Weevil days.
1902.	1902.			
September 4 to 5	September 17	3	12.5	37.5
September 9	September 16	5	7.0	35.0
October 2	October 16	4	14.0	56.0
November 9 to 10	November 16 to 17	7	7.0	49.0
November 11	November 19	3	8.0	24.0
Total		22		201.5
Average time after adult				9.0+

The average time of 5.5 days, as shown by the first generation, is probably about a day and a half longer than the minimum average period during the hottest weather, while the 9-day average found from September 4 to November 11 is considerably short of the maximum average just before hibernation.

EXAMINATION OF SQUARES BEFORE OVIPOSITION.

In the course of a great many observations upon oviposition it was found that females almost invariably examine a square quite carefully before they will begin a puncture for egg deposition. This examination is conducted entirely by means of senses located in the antennæ and not at all by sight. In fact, the sense of sight appears to be of comparatively small use to the weevil.

In regard to the actual time spent in the work of examination before beginning a puncture 60 observations were recorded. These show that the average time is over two minutes.

This examination of squares is made by females only when they intend to oviposit. Males have never been observed acting in this way, nor do females generally do so when their only object is to feed.

SELECTION OF UNINFESTED SQUARES FOR OVIPOSITION.

So unerring is the sense by which examination is made that in a few cases it was able to discover an infested condition no external sign of which was visible to the writer's eye. A female which was under close observation examined the square given her in the usual manner, but though evidently searching for a place to oviposit and anxious to do so, she plainly objected to placing an egg in that particular square. The writer again examined the square carefully, but found no sign of infestation and replaced it in the observation cage. Again the female made her usual careful examination and still she plainly refused to oviposit. Upon removing the covering from the square it was found to contain an egg, but the puncture made in depositing it had healed so smoothly that it had thrice escaped observation. The same female was then given two squares, one of which was known to be infested, the latter being placed nearer her. She examined it carefully, then left it, and went at once to the clean square, in which, after the usual examination, she deposited an egg.

The acuteness and accuracy of the preliminary examination is also well shown by the fact that when provided with more squares than they have eggs to deposit they rarely place more than one egg in a square. It was frequently found, however, that when a female deposited just as many eggs as there were squares present she would place two eggs in one and then make only feeding punctures in the remaining square.

The observations were made upon a large number of females; so there can be no doubt that the habit of selection is general. The conditions provided in these experiments were intended to resemble those existing in a slightly infested field early in the season, where each female could easily find an abundance of clean squares in which to deposit her eggs. Therefore only those cases were recorded in which the number of squares present equaled or exceeded the number of eggs deposited. Where a totally infested condition is reached no choice between infested and uninfested squares could be exercised, and then unless the female happened to be in a condition to refrain from oviposition she would be forced to deposit more than one egg in a square.

Not only do females show a strong inclination to place only one egg in each square, but they also object to making both egg and feeding punctures in the same square. That these conclusions are well grounded may best be shown by giving a summary of two long series of observations, the first made in the laboratory in the fall of 1902 and the other made in the field partly in the fall of 1902 and partly in the spring of 1903.

LABORATORY OBSERVATIONS.

Nine females were used in this series of experiments. The time followed varied with each individual, but ranged from October 23 to December 18, 1902. During this period a total of 868 uninfested squares was supplied to these 9 females. Of these squares 238 were not touched, while 630 were punctured, either for oviposition or for feeding or for both. The general results are here summarized in tabular form.

TABLE XIV.—*Selection of squares and relation of feeding to oviposition.*

No. of female.	Period of observation.	Squares supplied.	Squares with 1 egg each.	Squares with 2 eggs each.	Squares fed on only.	Squares with both eggs and feeding.	Squares untouched.
	1902.						
1	October 23 to November 15	135	72	2	25	1	35
2	October 23 to November 27	171	102	2	29	7	31
3	October 25 to November 7	96	74	4	8	1	9
4	October 23 to October 28	32	13	0	6	4	9
5	October 23 to October 28	38	30	1	2	2	3
6	November 10 to December 5	91	34	0	5	1	51
7	November 10 to November 25	75	41	3	7	1	23
8	November 10 to December 18	107	48	1	12	1	45
9	November 11 to December 12	123	63	6	16	6	32
	Total	868	477	19	110	24	238

A little calculation from these results shows that 82.5+ per cent of all squares attacked received eggs and that 91.7+ per cent of all squares oviposited in received only one egg each. The squares which were fed upon only formed 17.5− per cent of the total number attacked, and those receiving both egg and feeding punctures constitute only 3.8 per cent. The squares receiving two eggs each also form 3.8 per cent of all the squares which received eggs only.

The tendency to confine egg and feeding punctures to separate squares is strongly emphasized by the fact that in 17 instances, in which a total of 116 squares was provided, 91 received eggs only, while the remaining 25 were fed upon only; another total of 78 squares received 88 eggs in 72 of them, while the remaining 6 were fed upon only. As these two lots include nearly one-third of all the squares punctured, the tendency may be clearly seen.

FIELD OBSERVATIONS.

For one series of observations 500 infested squares were picked promiscuously in the field between May 28 and June 9, 1903.

A previous field examination was made about the middle of September, 1902, and this furnishes some very interesting comparisons as to the weevil's work upon the squares, especially at the beginning of the infestation and after it had reached its height. To facilitate an easy comparison, the results are arranged in Table XV.

TABLE XV.—*General results of observations upon selection of squares.*

	Total squares attacked.	Squares with 1 egg each.		Squares with more than 1 egg each.		Squares with both egg and feeding punctures.		Squares fed on only.	
		Number.	Percentage of all squares receiving eggs.	Number.	Percentage of all squares with eggs.	Number.	Percentage of total squares.	Number.	Percentage of total squares.
Squares infested in laboratory Oct. 23 to Dec. 2, 1902	630	477	91.7	19	3.8	24	3.8	110	17.5
Squares picked in field May 28 to June 9, 1903	500	317	79.25	83	20.75	50	10.0	110	20.0
Squares picked in field Sept. 17 to 22, 1902	105	56	62.9	33	37.1	46	43.8	16	15.2
Total	1,235	850		135		120		236	
Average percentage			84.2		13.4		9.7		18.3

A few obvious conclusions may well be stated here. Throughout the season from one-fifth to one-sixth of the squares injured were destroyed by feeding punctures alone. Within this small portion must be included most of the work of males and also of newly emerged females before they reach sexual maturity. As the weevil injury overtakes the production of squares it becomes increasingly difficult for females to find clean squares, and they are forced to deposit eggs in squares already injured and also to feed upon squares which already contain eggs. These conditions serve to increase most rapidly the proportion of squares containing both egg and feeding punctures. This is still further emphasized by the fact that in June only 30 per cent of all injured squares contained feeding punctures, while in September nearly 60 per cent had been thus injured. When females have access to an abundance of squares, they will deposit more than one egg only in about one-fifth of those in which they oviposit, while the proportion of those having both egg and feeding punctures is still smaller.

The tendencies to keep egg and feeding punctures separate, as well as to deposit only one egg in a square, serve to produce the greatest injury of which the weevils are capable for two obvious reasons: First, because where several eggs are placed in one square it is rarely the case that more than one larva develops. If two or more hatch in a square, one is likely to destroy the others when their feeding brings them together. They bite savagely at anything which irritates them, and larvæ have been found in the actual death struggle. Second, should eggs be placed in squares which already contained a partly grown larva, those hatching would likely find the quality of the food so poor that they would soon die without having made much growth. One egg will insure the destruction of the square, and a number of eggs, could all the larvæ live, would do no more. Therefore it is plain that the possible number of offspring of a single female is increased directly in proportion to the number of her eggs that she places one in a square, and favorable food conditions for the larva are best maintained by avoiding feeding upon squares in which eggs have been deposited, and also by refraining from ovipositing in squares which have been much fed upon. These habits of selections are, therefore, of the greatest importance in the reproduction of the weevil, since they insure the most favorable conditions for the maturity of the largest possible number of offspring. In other words, these habits enable the weevil to do the greatest damage of which it is capable while the cotton crop is "making."

These habits are perhaps less strongly marked in the case of bolls, though still plainly manifested. Feeding and oviposition are common in the same boll, but unless the infestation is very great indeed it appears that only rarely is more than one egg placed in one lock, though several are often deposited in the same boll. The number deposited depends considerably upon the size of the boll. The smallest, which have just set, receive but one, as do the squares, and these fall and produce the adult weevil at about the same period as in the case of squares. Bolls which are larger when they become infested are often found to be thickly punctured and sometimes contain 6 or 8 larvæ. The weevil seems to know when the food supply is sufficient to support a number of larvæ and deposits eggs accordingly.

ACTIVITY OF WEEVILS IN DIFFERENT PARTS OF THE DAY.

The 5 females used in these tests were kept in a field cage on previously uninfested plants, and examinations of their work were made mostly at four-hour intervals from 6 a. m. to 6 p. m. The exact work found was recorded upon tags attached to the squares themselves. Temperature readings were taken at the same time as the observations. The results are most clearly presented in tabular form (p. 64).

TABLE XVI.—*Activity of five weevils in different parts of the day.*

Date.	Period.	Temperature.	Number of squares attacked.	Number of egg punctures.	Number of feeding punctures.	Condition of weevil at end of period.	Remarks.
1903.		°F.					
Sept. 2	2.30 to 6 p. m	93–80	16	15	10	Placed on fresh plant.	
Sept. 2–3	6 p. m. to 6 a. m	80–69	3	1	2	All resting	Punctures black at 6 a. m.
Sept. 3	6.15 to 10.15 a. m	69–85	12	10	2	All active	3 trying to escape; cage moved.
Do	10.40 a. m. to 2.40 p. m	85–95	18	15	10	do	Cage moved.
Do	3 to 6.30 p. m	95–84	12	11	6	Placed on fresh plant.	
Sept. 3–4	6.30 p. m. to 6 a. m	84–68	3	1	3	All resting	Feeding punctures all black; small square flared.
Sept. 4	6.30 to 10 a. m	68–83	4	1	4	3 moving to adjacent squares.	
Do	10 a. m. to 4 p. m	83–91	24	19	12	All active	
Do	4 to 6 p. m	91–82	11	8	5	All quiet	
Sept. 4–5	6 p. m. to 9 a. m	82–79	5	0	6	All feeding	Cloudy; every weevil on same square as at 6 p. m.
	Total		108	81	60		

An examination of these figures shows that weevil activity began and ceased at about 75° F. Activity increased as the temperature rose, and its maximum coincided with the maximum of daily tem-

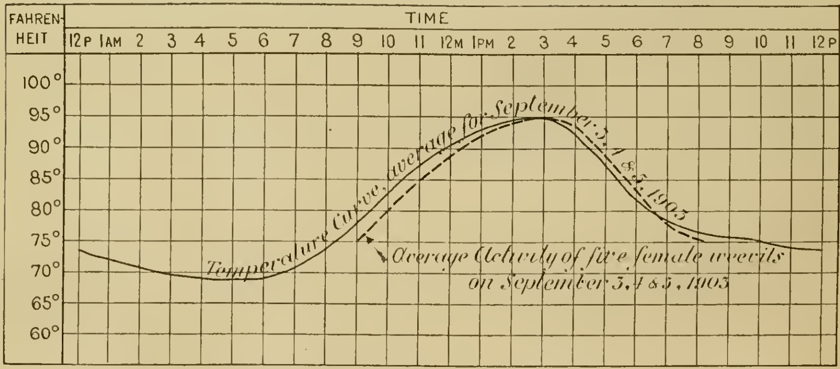


FIG. 3.—Diagram showing average activity of five female weevils. (Original.)

perature. It then decreased with the falling temperature until it ceased entirely some time during the evening, probably at about 75° F. See fig. 3. Feeding continued at lower temperatures than oviposition, as is known to be the case during the late fall.

Examinations made in the field between 6 and 7 a. m. on September 4 showed that all weevils, both males and females, were quietly resting at that time with the temperature at about 70° F. On cloudy days the activity is less than it is on clear days.

FIG. 43.—THREE LARGE LARVÆ IN A BOLL, TWO-THIRDS NATURAL SIZE. (ORIGINAL).

FIG. 44.—FOUR PUPAL CELLS FROM BOLLS (ON LEFT) COMPARED WITH FOUR COTTON SEEDS (ON RIGHT), NATURAL SIZE. (ORIGINAL.)

TESTING DEVICES. FALLEN AND HANGING INFESTED SQUARES.

Fig. 45, Device used to test attraction of molasses in the field in the spring; fig. 46, fallen squares on ground in field; fig. 47, infested squares dried and still hanging upon the plant; fig. 48, device used to test relative attractiveness to weevils of American and Egyptian squares. (Original.)

PLACE OF EGG DEPOSITION.

The location of egg punctures, while variable, still shows some selection on the part of the weevil. This may be due partly to the form of the squares and partly also to the size of the weevil, but whatever the explanation the fact remains that in a majority of cases the egg puncture is made on a line about halfway between the base and tip of the square. When so placed the egg comes to rest either just inside the base of a petal or among the lowest anthers in the square, according to the varying thickness of the floral coverings at that point (Pl. I, fig. 3). Punctures are very rarely made below this line, though they are sometimes made nearer the tip. Almost invariably the egg puncture is started through the calyx in preference to the more tender portion of the square, where the corolla only would need to be punctured. The reason for the choice of this location may be found under the subject of the "Relation of warts to oviposition," on page 69.

With bolls no selection of any particular location has been found, but eggs seem to be placed in almost any portion. Pl. X, fig. 41, shows the egg deposited inside the carpel.

POSITION OF THE WEEVIL WHILE PUNCTURING FOR OVIPOSITION.

While engaged in making egg punctures the favorite position of the weevil is with its body parallel to the long axis of the square and its head toward the base of the same. The tip of the weevil's body is thus brought near the apex of the medium size square. Having selected her location, the female takes a firm hold upon the sides of the square and completes her puncture while in this position. It may be that the position described is especially favorable for obtaining a firm and even hold, and this may have something to do with the regularity with which it is assumed. If so, the apparent choice of this location for the puncture is only partially explained, since it has been often shown that weevils can puncture and oviposit successfully in almost any portion of the square except its very tip.

Undoubtedly there are other reasons than those of mere convenience which have so impressed themselves upon the inherited experience of the weevils as to lead them to the choice of this position and the consequent location of the punctures and eggs. Most apparent of these reasons, and probably also most important, is the advantage which this location affords in the protection of the egg and the young larva developing from it against the attacks of natural enemies as well as from the injurious effects of drying and decay.

This protection is readily explained by several facts. The place chosen is through the thickest and toughest portion of the floral envelopes through which the anthers can be reached, since the thickest parts of both calyx and corolla are toward their bases. More important than the thickness of the layers of vegetable matter is the character of the tissues through which the puncture passes. Though corolla and calyx are both modifications of original leaf tissue, both have changed so greatly in form and texture that the resemblance is recognized only by those somewhat acquainted with plant structure. The corolla, moreover, has changed far more than has the calyx, and in becoming so highly specialized its tissue has lost certain powers still retained by the green calyx tissue. The particular power referred to in this connection is the ability to heal small wounds. Punctures made in the corolla must, therefore, remain open, while small punctures through the calyx will in most cases be healed by the natural outgrowth of the tissue, so as to completely fill the wounds in a manner entirely analogous to the healing of wounds in the bark of a tree. The custom of the weevil of sealing up its egg punctures with a mixture of a mucous substance and excrement is of great advantage and assistance to the plant in the healing process. While undoubtedly applied primarily as a protection to the egg, it serves to keep the punctured tissues from drying and decay, and thus promotes the process of repair.

As a result of the growth thus stimulated in the calyx, the wound is perfectly healed in a short time, and, as is the case in the healing of the bark of trees, here also we find a corky outgrowth projecting above the general surface plane. This prominence the writer has termed a "wart" (Pl. X, fig. 40). The healing is completed even before the hatching of the egg takes place, and thus both egg and larva partake of the benefit of its protection.

It is possible for the puncture to heal without the full development of the wart, and it is also possible for eggs to develop successfully even when the puncture was made through the corolla alone and no wart developed, but in the latter case the chances are rather against it. Occasionally warts do develop from feeding punctures which were small, but the exact conditions under which this takes place have not been determined.

THE ACT OF OVIPOSITION.

The general process of making punctures has been described previously under the topic of "Food habits" (p. 38), and will therefore not be repeated here. Having completed the formation of the egg cavity, the female withdraws her proboscis and turns end for end. She depresses the tip of her abdomen and locates therewith the opening to the cavity by feeling or scraping around. In a majority of cases the opening is readily found, but sometimes it is not. Then the female seems often to lose all sense of locality, but continues scraping with the tip of her abdomen. If she is still unsuccessful, she turns and continues the search by means of the antennæ, just as in the preliminary examination of a square before beginning a puncture.

In many cases females were noticed to actually place the tip of the proboscis within the opening of the cavity without seeming to be aware of its proximity. When the cavity has been found again by the antennal senses, the female invariably enlarges it before turning again to insert the ovipositor. If the search with the antennæ does not prove successful, the female will make another puncture in the same manner as at first, appearing to know that no egg has yet been placed in that square.

After locating the cavity by the tip of the abdomen, the ovipositor is first protruded to the bottom of the cavity, in which it appears to be firmly held in position by the two terminal papillæ and the power of enlarging the terminal portion of the ovipositor. Slight contractions of the abdomen occur while this insertion is being made. In a few moments much stronger contractions may be seen, and often a firmer hold is taken with the hind legs as the egg is passed from the body, and its movement may be seen as it is forced along within the ovipositor and down into the puncture. Only a few seconds are required to complete the deposition after the egg enters the opening to the cavity. The ovipositor is then withdrawn, and just as the tip of it leaves the cavity a quantity of mucilaginous material, usually mixed with some solid excrement, is forced into the opening and smeared around over the same by means of the tip of the abdomen. This seals the egg puncture and the act of oviposition becomes complete (Pl. X, fig. 39).

TIME REQUIRED TO DEPOSIT AN EGG.

Observations upon this point were very conveniently made by confining females upon squares from which the involucres had been removed. A plain glass cover allowed accurate observations, which were made to the fraction of a minute. The time required to complete the excavation and the time required to place the egg were the two points especially noted.

The time of making the puncture was noted in 115 instances, and this was found to average 5¼ minutes. The time varied widely, being from 1 to 13 minutes; the usual range was from 4 to 8 minutes. From the time that the weevil began to puncture till the sealing of the cavity the complete act of oviposition required in 103 instances an average of slightly over 7½ minutes, ranging in time from 3 to 16 minutes.

As these observations were made between October 7 and 23, the periods given may be slightly longer than they would be in warmer weather. However, various observations made in the field in midsummer agree very closely with the averages given.

RATE OF OVIPOSITION.

Since the period of reproductive activity of the boll weevil is so long, the rate at which eggs are deposited is a question requiring much time for its determination. There have been found great variations in the rate at different seasons, and it is clear that oviposition is even more strongly influenced by variations in temperature than is feeding. The rate sometimes varies unaccountably and very abruptly with the same female upon succeeding days. No explanation for this has as yet been found. The rate is influenced also by the abundance of clean squares which the weevil can find, so that it is greater in the early season, as the degree of infestation is approaching its limit, than after infestation has reached its maximum.

Two extended series of observations have been made to determine especially the normal average and the maximum ability of the female.

AVERAGE.

Taking first 54 females which had gone through hibernation, we find that they deposited on the average 2½ eggs each daily in the laboratory, and 4 females which were followed under field conditions for a total of 93 "weevil-days" deposited 489 eggs during that time, or at the rate of 5¼ eggs each per day. Where the rate of activity is so great it is probable that the length of the period would be somewhat, but not proportionately, shortened. From many observations made in the field during the beginning of the squaring season it seems probable that a rate of 5 eggs a day is not far from the average in the field.

From 27 females of the first generation a laboratory average rate of 2⅓ eggs each daily was obtained. Five females of this generation confined in a cage in the field during the latter part of August for a total of 70 "weevil days" deposited an average of 6⅕ eggs per day. This latter rate is far beyond the actual average rate in the field at that period because of the fact that the weevils can not at that time find enough uninfested squares to lead them to deposit so many eggs, but the possibility remains if only squares enough are present.

A few words must be said in further explanation of the differences which appear between the field and laboratory results. In the case of the laboratory figures the entire oviposition period of each weevil and the entire number of eggs deposited are taken into the account. As there is a gradual increase in the rate of production of eggs after the beginning of deposition and a gradual decrease from the middle of the period to its end, the general average is much lower than would be that taken at the time of maximum activity. In the case of the field figures a short period only is covered, and all conditions of square supply were such as to stimulate the weevil to its greatest possible activity.

MAXIMUM.

The daily observations made upon the weevils in the laboratory supply a vast number of observations from which to select maximum figures. It has been shown that under favorable conditions weevils may be expected to produce an average of 6 eggs a day for a considerable period of time. It is not surprising, therefore, that some of the maximum figures obtained are very much larger than that number. A few instances only will be taken from among thousands of daily records.

The highest record of eggs deposited shows that 2 small females deposited together 108 eggs in 3 days, or at the daily rate of 18 eggs each. This record was made on the 7th, 8th, and 9th of June, 1903.

TABLE XVII.—*Maximum rate of oviposition.*

Number of females.	Days included in period.	Total eggs deposited.	Average per day.	Number of females.	Days included in period.	Total eggs deposited.	Average per day.
2	3	108	18.0	2	2	43	10.8
1	5	76	15.2	1	3	30	10.0
2	5	160	16.0	2	5	114	11.4
5	1	55	11.0	3	2	54	9.0
2	2	47	11.8	5	1	42	8.4
12	16	446	13.5	13	13	283	9.5

STIMULATING EFFECT OF ABUNDANCE OF SQUARES UPON EGG DEPOSITION.

Four actively laying females were confined together upon a few squares from September 22 till October 14, 1902, and during this period they laid a total of 227 eggs, or an average of 2.37 eggs per weevil per day. For the next 13 days these same weevils were isolated and supplied with an abundance of squares. During this shorter period they laid 236 eggs, or 4.54 eggs per female daily.

Taking equal periods as near together as possible and using these same weevils, there were deposited in 13 days upon a few squares 144 eggs, or 2.74 eggs per female daily, while during the following 13 days, with an abundance of squares, they each deposited 4.54 eggs a day.

These figures are the more striking because the stimulation was plainly shown in spite of the general tendency to lay fewer eggs as the weevils grow older and as the average temperature becomes lower.

RELATION OF WARTS TO OVIPOSITION.

When the general relation of the warts to the formation of egg punctures was first recognized, an investigation was undertaken to determine, if possible, in what proportion of cases the warts could be traced directly to egg or feeding punctures. For this purpose a large number of squares, most of which had warts, was picked from plants in the field and carefully examined in the laboratory. Notes were made especially upon the following points: The number of warts, the number of punctures obviously made for feeding only, the number of special egg punctures, and the numbers of eggs, larvæ, and pupæ found. Only those excrescences were counted as warts which showed a positive elevation, and, as was expected, many eggs were found which had not been deposited long enough for a wart to have formed. Out of the 105 squares examined, 26 showed no warts, while the remaining 79 squares had 92 warts. In tracing the connection of these 92 warts it was found that 77 at least, or almost 84 per cent of the total, resulted from egg punctures. The other 15 warts, or 16 per cent, were assigned to feeding punctures, though some of these may possibly have been egg punctures in which decay had concealed all trace of the eggs or small larvæ. One-half of the eggs found were in punctures closed by developed warts, and it is likely that most of the other half were of too recent deposition for warts to have formed. Three-fourths of the larvæ found in this lot were in punctures which had been overgrown by warts.

In another series of 35 older squares, 38 warts and 32 eggs, larvæ, and pupæ were found. This series also shows that at least 84 per cent of the warts resulted from egg punctures. The conclusion seems justified, therefore, that warts may be considered as the most conspicuous external indication of the presence of the weevil in some stage within the square.

It should be noted in connection with warts that feeding frequently, and oviposition more rarely, is followed by a peculiar gelatinization of the injured portion of the square. This condition spreads, and the change produces a considerable internal pressure, so that the square becomes distorted and bulges, especially at the place where the puncture was made. The bulging portion often resembles somewhat a wart formation, but its real nature is very different. In many cases the gelatinized condition appears to have caused the death of the young larvæ, either by the pressure or by the abnormal condition of the food supply. In a large number of cases, however, this condition undoubtedly results from what were feeding injuries only.

EFFECTS OF OVIPOSITION UPON SQUARES.

The method of recording the progress of injury to each square, as was done in the field cages, has furnished much data upon a number of important points. Among these the two of most importance are, in order of their occurrence, the flaring and the falling of the square.

FLARING.

The flaring of squares (Pl. X, fig. 42) is one of the most apparent signs of weevil presence, although by no means an invariable accompaniment, as it is usually thought to be. Squares flare in nearly as large a proportion of cases from adult feeding injury alone as from larval injury within. Any injury severe enough to cause the falling of the square is as liable to cause flaring as is the larva of the weevil. Flaring results from an unhealthy condition, whatever may be the cause, and is frequently to be seen in squares which are about to be shed, though they have never been injured by any insect. However, flaring has come to be popularly associated with weevil injury, and must therefore be quite fully considered.

When resulting from weevil injury, flaring does not begin, as a rule, immediately after the injury, but only within from one to three days of the time when the square will be ready to fall. In especially severe cases of feeding injury, flaring often results in less than twenty-four hours. Occasionally the growth of the square overcomes the injury from feeding and the involucre, after having flared, again closes up and the square continues its normal development as though uninjured, and forms a perfect boll. More frequently the square gradually loses its healthy green, becoming a sickly yellow in color, and falls in a short time.

When injured by the feeding of a young larva as the direct result of successful oviposition, flaring has been found in an average of 139 cases to take place in almost exactly 7 days from the deposition of the egg. These observations cover the season from June to September, when the developmental period averages about 19 days. Fully one-third of the weevil's full development has, therefore, taken place before flaring results.

FALLING.

Squares which flare because of injury from larval feeding within always fall, except the small percentage which, though entirely cut off from all vital connection with the plant, still remain hanging thereon by a small strip of bark and gradually become dry and brown upon the plant. Falling is but the natural final consequence of injury or disease (Pl. XII, fig. 46). Whatever its cause, it is brought about in exactly the same way as the shedding of leaves by the plant in the fall, by the formation of an absciss layer of corky tissue cutting off the fibro-vascular bundles supplying nourishment to the square. The exact location of the cork area is to be seen at the scar left by every fallen square.

In 539 cases definitely noted between June and September, 1903, the average time from egg deposition to the falling of the square was 9.6 days. For this same period full development required an average of 19 days, so that falling occurred at the middle point in the weevil's development. From a comparison of the time of flaring with that of falling it is seen that the interval between these two points averages about 2.5 days. In late fall the time between oviposition and falling, as recorded in 21 cases, was found to be about 16 days.

PERIOD OF OVIPOSITION.

With the exception of hibernated weevils, it appears that oviposition begins with most females within a week after they begin to feed and continues uninterruptedly until shortly before death. While females frequently deposit their last eggs during the last day of their life, a period of a few days usually intervenes between the cessation of oviposition and death.

In the case of 52 hibernated females the actual period of oviposition averaged about 48 days, the maximum being fully 92 days.

In an average made with 21 females of the first generation the actual period was almost 75 days, the maximum period being 113 days.

The average period for the females of the first two generations appears to be longer than that for any other. In the third generation the average period for 11 females was 58 days, the maximum being 99 days, and in the fifth generation for 5 females the period averaged 48 days, with the maximum only 62.

The approach of cold weather cuts short the activity of the weevils, which become adult after the middle of August, thereby decreasing the length of their oviposition period. Weevils which pass through the winter actually live longest, but as it must take more or less vitality to pass through the long hibernation period their activity in the spring is thereby lessened.

The weighted, average period of oviposition of the 89 females here mentioned is 55.6 days.

DOES PARTHENOGENESIS OCCUR?

To test the possibility of weevils reproducing parthenogenetically, 12 individuals were isolated from the very beginning of their adult life. Each beetle was supplied daily with fresh, clean squares and careful watch was kept for eggs. The first noticeable point was that no eggs were found till the weevils were about twice as old as females usually are when they deposit their first eggs. After they began to oviposit, it was found that a very small proportion of the eggs were deposited in the usual manner within sealed cavities in the squares, but nearly all of them had been left on the surface, usually near to the opening to an empty egg puncture. This same habit was shown by a number of females, and so can not be ascribed to the possible physical weakness of the individuals tested. The number of eggs deposited was unusually small, and those few placed in sealed cavities failed to hatch. After somewhat more than a month had been passed in isolation, one pair was mated to see if any change in the manner of oviposition would result. The very next eggs deposited by this fertilized female were placed in the square and the cavity sealed up in the usual manner, showing that her infertile condition had been the cause of her abnormal manner of oviposition.

A much more extensive series of experiments along this line is desirable and will be made.

DEVELOPMENT.

PERCENTAGE OF WEEVILS DEVELOPED FROM INFESTED SQUARES.

During the season of 1902 part of the many squares gathered in infested fields for the breeding of weevils were followed to learn something of the percentage which produced normal adults. No examination was made for those not yielding a weevil. The decay of the square during the period from its falling to the maximum time that must be allowed for weevils to escape normally so obliterates any small amount of work by a larva that it is difficult even with examination to determine accurately the number of dead small larvæ.

TABLE XVIII.—*Percentage of weevils from infested squares.*

Locality.	Approximate date.	Number of squares.	Number of weevils.	Percentage of squares producing weevils.
	1902.			
Victoria, Tex	July to August	1,125	360	32.0
Guadalupe, Tex	August	387	108	28.0
	1903.			
Victoria, Tex	June	334	106	32.0
Do	June to August	873	355	41.0
Do	August to September	368	192	52.0
Total		3,087	1,121	36.3

It seems safe to conclude that throughout the season fully one-third of the squares which fall after receiving weevil injury may be expected to produce weevils.

DEVELOPMENT OF WEEVILS IN SQUARES WHICH NEVER FALL.

It is generally true that squares seriously injured by the weevil sooner or later fall to the ground. Some plants, however, shed the injured squares more readily than do others. It seems to be a matter of individual variation rather than a varietal character. Thus occasional plants retain a large proportion of their infested squares, which hang by the very tip of the base of the stem. Normally the squares are shed because of the formation of an absciss layer of corky tissue across their junction with the stem. In the case of the squares which remain hanging the formation of this layer seems to be incomplete, or else it becomes formed in an unusual plane, so that while the square is effectually cut off, it merely falls over and hangs by a bit of bark at its tip (Pl. XII, fig. 47). In this position it dries thoroughly and becomes of a dark-brown color. Plants showing 6 or 8 of these dried brown squares are quite common in infested fields. Although exposed to complete drying and the direct rays of the sun, the larvæ within are not all destroyed. This peculiarity reminds one strongly of the European *Anthonomus pomorum* the work of which in causing apple buds to hang dead upon the trees has caused the common name of "Brenner" to be applied to it.

At intervals during the summer of 1903 such dried squares and small dried bolls were picked for careful examination in the laboratory, the condition of 342 being recorded, with the following results:

Adults present 2, escaped 23; pupæ alive 29, dead 2; larvæ alive 85, dead 47; parasites present 44, escaped 6. Sixty-three squares which failed to show weevil work and 42 small dried bolls from which the corollas had fallen were probably destroyed largely by the feeding of the weevils. Taking the total number of squares and bolls examined as the basis of computation, it appears that 69.3 per cent of them showed weevils present in some stage. Of the immature stages, 30 per cent were dead, 14.6 per cent having been parasitized. It seems a conservative estimate therefore to say that fully one-third of these exposed dried squares may be expected to produce adults. Considering the exposed condition of such squares this seems to be a very high percentage.

The season of 1903 was not as hot at Victoria as was that of 1902, and the lower temperature prevailing may have favored the development of a larger proportion of the weevils in these squares than would normally emerge. The maximum temperature reached in 1902 was 104.3° F., while in 1903 the maximum was only 97.5° F. No examinations of this subject were made in 1902, and therefore no positive comparisons can be drawn. The observations made, however, certainly show that a complete drying of the square does not necessarily destroy the larva, and that a square may undergo far more exposure to direct sunshine than had been supposed possible without causing the death of the larva or pupa within.

LENGTH OF THE LIFE CYCLE.

This question has been studied carefully, both in the laboratory and in the field. Most of the observations made in 1902 were in the laboratory, while those of 1903 were in the field.

In the laboratory uninfested squares were exposed to active weevils for oviposition, and the supply of clean squares was renewed each day. The beginning of the cycle was thus known to within a few hours. The squares with eggs were carefully kept and the date of emergence of each adult was then noted. To the period thus found must be added the time intervening between the leaving of the square and the deposition of the first eggs. This gives the length of the life cycle. The material upon which these observations were made was necessarily other than that used in determining the length of the various stages. The period in bolls is far different from that in squares. The figures here given refer to squares.

TABLE XIX.—*Length of life cycle.*

Observations.		Time in period of development.		Average time.		Temperature.	
Period covered.	Number.	Range.	Average.	Adult to oviposition.	Length of cycle.	Average effective.	Total effective.
1902.		*Days.*	*Days.*	*Days.*	*Days.*	*°F.*	*°F.*
August 10 to September 30	96	10–18	13.4	5.0	18.4	41.0	754.4
September 16 to October 15	305	12–25	17.5	7.0	24.5	33.64	823.2
October 8 to November 16	66	14–23	20.2	9.0	29.2	29.5	864.4
1903.							
Field, first generation:							
June 4 to July 15	100	12–22	18.3	5.6	23.9	32.0	764.8
August 20 to September 28	180	13–26	19.0	5.0	24.0	33.1	794.4
Total	747	10–26					
Weighted average			17.8	6.2	24.0	34.1	818.4

These observations cover the season from June 4 to November 16. Reproduction undoubtedly begins somewhat earlier and continues later in the average season at Victoria, but any differences which might be found at the extremes would not materially affect the location of the mean in so large a series. The influence of varying temperature during the same period but in different seasons is clearly seen by a comparison of the figures for August 10 to September 30, 1902, with those for August 20 to September 28, 1903. The period for 1902 was exceptionally warm, as shown by the high average effective temperature, while in 1903 it was decidedly cooler, the difference averaging 8° F.; consequently the average length of the cycle was fully six days greater in 1903 than in 1902 at the same period.

Determinations of the length of the life cycle in bolls have been made in only a few instances. In 7 cases between August 15 and November 11, 1903, the average time required from the deposition of the egg to the escape of the adult from the opening boll was 61 days. The average effective temperature for the period was 31.7° F., and the average total effective temperature required for development in bolls was therefore 1,933.7° F., or nearly two and one-half times as much as in squares. Several larvæ often develop within a single boll (Pl. XI, fig. 43). They appear to remain in the larval stage until the boll becomes sufficiently mature or so severely injured as to begin to dry and crack open. When this condition of the boll is reached, pupation takes place, and by the time the spreading of the carpels is sufficient to permit the escape of the weevils they have become adult.

BROODS OR GENERATIONS.

The term "brood" can hardly be applied in its usual sense to the generations of the weevil, as was pointed out by Doctor Howard in the first circulars of the Division dealing with the problem. For several reasons no line of distinction can be drawn between the generations at any season of the year, not even between hibernated weevils and the adults of the first generation. As has been shown, the average period of oviposition among hibernated females is in some cases fully 3 months, while it averages 48 days. The length of the full life cycle for the first generation, as shown in Table XIX, is 24 days, and as the time for the second generation would be slightly less, it is evident that the first eggs for the third generation will be deposited at the same time as those for the middle of the second generation, and also with the very last of the eggs deposited by hibernated females for the first generation. The great overlapping of generations thus produced prohibits the application of any of the common methods of ascertaining their limits. The complexity indicated for the first three generations becomes still further increased as the season advances, so that in October, for example, a weevil taken in the field might possibly belong to any one of six generations. Length of life and the period of reproductive activity are important factors in determining the average number of generations. Periods of greatest abundance can not be regarded as giving any reliable information upon this point, since the number of weevils developed soon comes to depend largely upon the supply of squares.

In the case of the boll weevil, therefore, the information upon the number of generations must be drawn from laboratory sources. Many of the hibernated weevils continue to deposit eggs until the middle of July, and some are active for fully a month longer. In 1903 the last eggs from hibernated weevils were deposited on August 27. In the course of breeding experiments made in 1902 it was found that many weevils which had become adult about the 1st of August would continue to deposit eggs until the latter part of November. Considering the longest-lived weevils and their last-laid eggs, therefore, it is easily possible for two generations to span the entire year. The weevils developing after the middle of November may go into hibernation, and from their last-deposited eggs produce weevils whose last offspring will be ready for successful hibernation again. This conclusion is based upon actual demonstration.

The maximum number of generations will be found by taking the first, instead of the last, deposited eggs in each case. Rather than lay the conclusions open to question by taking the figures found for occasional minimum length of the life cycle, we will take the 24-day period, which has been shown to be the average between June 4 and November 16. Without doubt hibernated females begin their reproductive activity in average seasons by May 1, and their descendants continue to develop normally until after November 15. Taking the dates mentioned, however, as the average season for the weevils, we find that eight generations, each having the average period of development, may usually be produced within the year.

In determining the average number of generations one-third the average period of oviposition should be added to the average life cycle for each generation.[a] As it has been found that the average period of oviposition is about 5½ days, we must allow 24 days for the development of the average adult and 18 more days for the female to deposit one-half her eggs. Forty-two days is therefore about the average length of a generation; and we may thus count on an average of about five generations between May 1 and December 1. In the northern part of the weevil territory, where the season is shorter and the prevailing temperature lower, probably only four generations would be developed.

There is no basis for the idea that there is a distinct hibernation brood. The activity of the adults and the development of the immature stages is gradually retarded by the decline in temperature until hibernation time arrives. Most of the weevils of the first two or three generations have probably died, or then do so, while most of the adults of later generations, having still considerable vitality, will go into hibernation. It is certain that every generation preceding may have some direct part in the production of weevils which shall hibernate. All weevils which are still strong and healthy when cold weather comes on may be expected to go into hibernation, so that there can be no special brood for this purpose.

THERMAL INFLUENCE UPON ACTIVITY AND DEVELOPMENT.

The influence of temperature has been frequently mentioned as an important point, but it may be more clearly understood by collecting some of the most important observations relating to it. A study of this subject throws much light upon such questions as seasonal and daily activity, the rapidity of development at various seasons, hibernation, and the time of emergence from hibernation. The influence upon development will be first considered.

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[a] One-third is nearer the correct fraction than one-half, since it has been found that weevils deposit considerably more than one-half of their eggs during the first half of their oviposition period.

TABLE XX.—*Thermal influence on development.*

Stage.	Number of observations.	Period.	Average time for stage.	Effective temperature. Average.	Effective temperature. Total.
		1902.	*Days.*	°*F.*	°*F.*
Egg	385	Sept. 4 to Oct. 3	3−	38.0	114.0
	107	Oct. 7 to Nov. 13	4+	30.0	120.0
	36	Nov. 24 to Dec. 15	11.0	19.0	209.0
Larva	195	Sept. 6 to Oct. 5	7.5	35.7	267.7
	15	Sept. 26 to Oct. 21	9.5	30.6	280.7
	15	Nov. 11 to Dec. 12	25.0	19.5	487.5
Pupa	161	July 6 to 31	3.5	39.65	138.8
	81	Sept. 15 to Oct. 3	5.2	36.0	187.2
	167	Sept. 24 to Oct. 28	6.0	31.1	186.6
	29	Nov. 2 to 13	7.6	26.2	199.1
	4	Dec. 2 to 29	14.5	18.5	268.2
Entire developmental period	96	Aug. 10 to Sept. 30	13.4	41.0	549.4
	305	Sept. 16 to Oct. 15	17.5	33.6	588.0
	66	Oct. 8 to Nov. 16	20.3	29.5	598.8
		1903.			
	100	June 4 to July 15	18.3	32.0	585.6
	185	Aug. 20 to Sept. 28	19.0	33.1	628.9

SUMMARY OF THE PRECEDING TABLE.

Stage.	Total observations.	Average period for stage.	Average effective temperature	Total effective temperature.
		Days.	°*F.*	°*F.*
Egg	528	3.75	35.1	141.6
Larva	225	8.8	34.3	301.8
Pupa	442	5.1	34.7	177.0
Total development	1,195	17.65	34.8	614.2
Observations on entire period	752	17.7	33.9	600.0

In studying the influence of temperature on development the figures upon the separate stages serve best, as they give the widest range. In each stage it may be seen that the maximum time is nearly, if not quite, four times the minimum, while the average effective temperature difference is in the inverse order, but about 2 to 1. In comparing the minimum and maximum total effective temperatures, it appears that when the average temperature is lowest the total heat required to complete the development of the stage is nearly twice as great as when the average temperature is highest. The length of the developmental period is therefore not exactly inversely proportional to the change in temperature. The retarding influence of decreasing temperature appears to affect each of the immature stages in very nearly the same degree. The total effective temperature required forms a specific constant, which is fairly uniform for average effective temperatures of between 30° and 40° F. These temperatures would, during most seasons, prevail from June to October, inclusive. As the average effective temperature falls below 25° F., however, there results a great and disproportionate retardation in the development. The reason for this difference may lie in the fact that when temperature is ascending from 32° F. it must attain a higher point to start weevils into activity than that at which the same weevil will cease activity when the mercury is going down.

The observations upon the length of the entire developmental period were made upon a different series of weevils. As is clearly shown in the summary given in the latter part of the table, the sum of the average lengths of the three stages agrees remarkably closely with the length of the entire period as found in the 752 cases observed. This close agreement, reached by entirely different methods, indicates that the series from which the averages are obtained are sufficiently large to give constant results, and therefore that the average period of development throughout the season of weevil activity is very close to 18 days.

This thermal influence upon activity in feeding and oviposition may be shown by taking various lots of weevils at intervals through the season. For this purpose the work of 10 males and 10 females has been selected, using the laboratory records for each lot. The time covered is 25 days in each case to secure a fair average, and 25-day intervals separate the lots from each other. The season thus covered begins with June 6 and ends with November 28, 1903. To make the comparison fair, average conditions as to sex, age, and individual activity must be established, and the records have been selected with these conditions in view.

TABLE XXI.—*Thermal influence on activity in feeding and ovipositing.*

Number of males.	Number of females.	Period.	Average effective temperature.	Total.		Daily average.		Average per weevil daily.	
				Feeding punctures.	Eggs.	Feeding punctures.	Eggs.	Feeding punctures.	Eggs.
		1903.	°*F.*						
10	10	June 6 to 30	32.1	2,189	794	87.6	31.8	4.4	3.2
10	10	July 25 to Aug. 19	36.5	2,325	1,061	93.0	42.4	4.7	4.2
10	10	Sept. 14 to Oct. 8	32.7	1,540	659	61.6	26.4	3.1	2.6
10	10	Nov. 3 to 27	24.6	900	217	36.0	8.7	1.8	0.9

The average number of daily feeding punctures is reckoned for both sexes alike. Though the females made more than half, the proportions can not be positively separated, and it would make no difference if we could do so. It is noticeable that the period of greatest activity comes in midsummer, with the first, second, and third generations actively at work. Hibernated weevils working in June show greater activity than do the mixed generations which occur together in September and October, though the temperature does not greatly vary. In November, with a marked fall in temperature, there is a corresponding decrease in work, but especially is this noticeable in egg deposition. It appears that at this season and later on the weevils are mostly eating to live until it becomes cold enough for them to hibernate.

LABORATORY EXPERIMENT IN EFFECT OF TEMPERATURE UPON LOCOMOTIVE ACTIVITY.

The experiments here given were performed by Dr. A. W. Morrill. In the absence of apparatus especially designed for such work, use was made of a very simple device, constructed as follows:

A thermometer was passed through a cork and inclosed in a test tube, which in turn was placed within a hydrometer cylinder of sufficient depth to inclose it (Pl. XIII, fig. 49).

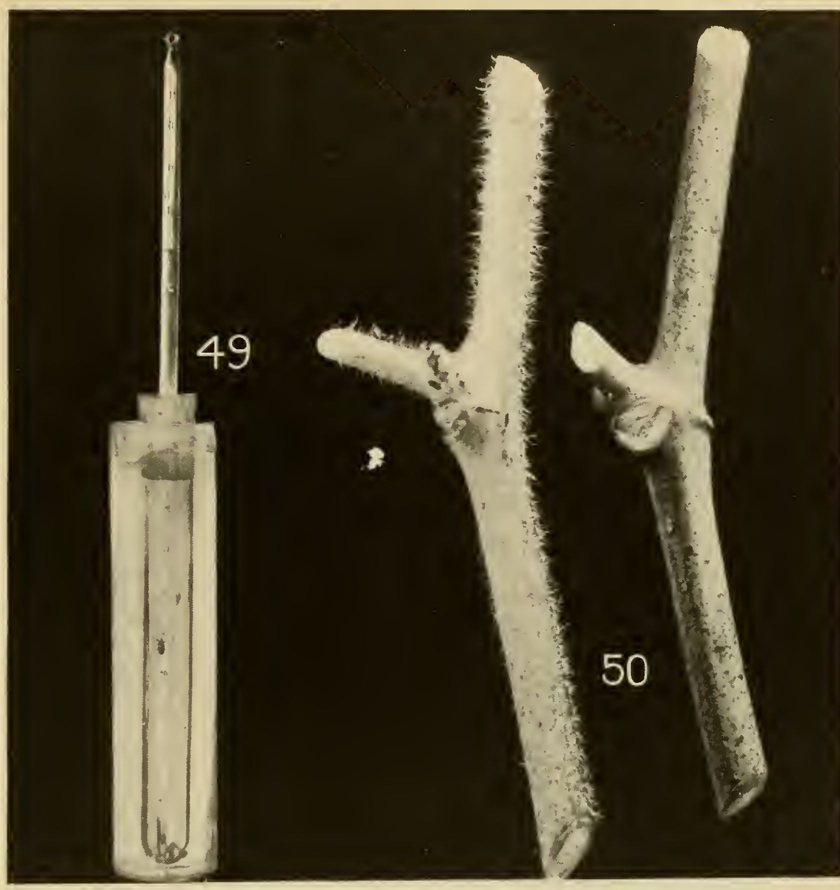
Weevils were inclosed in the test tube with the thermometer, and the temperature of the cylinder varied either by heating gently or by the use of ice water. Starting with the thermometer at 64° F., the 10 weevils inclosed were found to move slowly, half of them being quiet. As the temperature was gradually raised the activity of the weevils increased up to 105° F. When the temperature reached 95° F., or over, the weevils were running up and down the tube. By filling the cylinder with cold water the temperature was lowered to 86° F., at which point the weevils began to cluster at the top on the cork and were crawling slowly. By the addition of ice in the cylinder the temperature was lowered to 59° F., at which point 5 weevils were sprawling on the bottom of the test tube or clinging to one another, 4 were clustered on the stopper, while 1 was slowly crawling downward. At 50° F. 6 weevils at the bottom showed slight signs of life and 1 was crawling slowly. At 45.5° F. slight signs of life were still shown, while at 40° F. occasional movements only were noted. Upon the temperature being raised weevils began crawling as 50° F. was passed, and at 64° F. all had left the bottom and were crawling upward. Some recovered much more quickly than did others.

The temperature was again lowered, this time by the use of salt with ice. All movement ceased at 37° F. The cooling, however, was continued to 33° F., after which it was slowly raised to 42° F., at which point movements began.

In a general way these results agree quite closely with outdoor observations.

HIBERNATION.

Even after frosts have blackened the foliage and squares and entirely checked the growth of the plant, some weevils can be found moving in a cotton field upon warm days. Weevils which are old and nearly exhausted die as the cold weather comes on. Their vitality has been expended in other ways and they do not survive the winter. Those which are still vigorous and strong will continue to feed a little, and females will occasionally deposit eggs so long as cotton remains green. In southern Texas larvæ and pupæ which are in squares when frost comes are not killed thereby, but slowly finish their development if the weather is warm enough for any activity, and the young adults thus developed may live the winter through without feeding. As

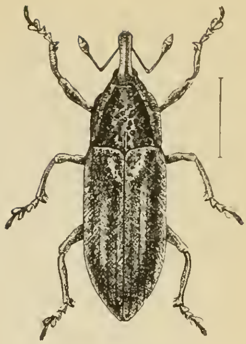


FAVORABLE AND UNFAVORABLE CONDITIONS FOR WEEVIL ACTIVITY.

Fig. 49, Device used to test effect of temperature upon weevil activity, one-third natural size; fig. 50, comparison of pilosity on "King" (at left) and "Mit Afifi" (at right) stems, natural size; fig. 51, locality found very favorable to hibernation of many weevils. (Original.)

52

53



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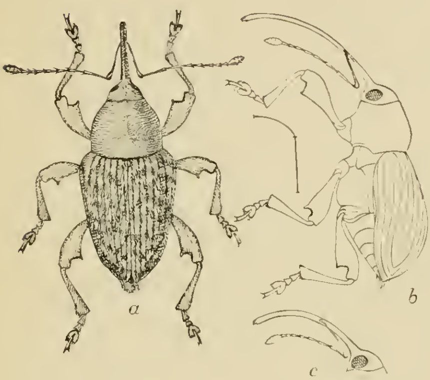

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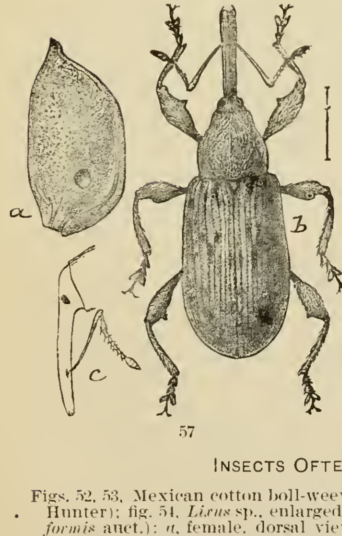

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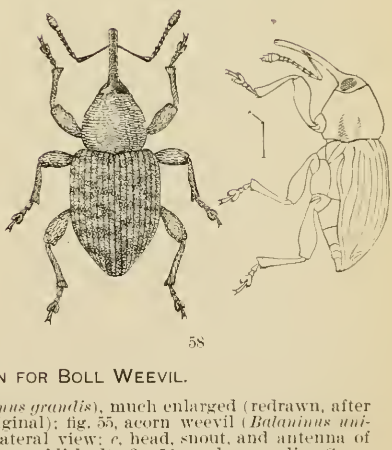


58

INSECTS OFTEN MISTAKEN FOR BOLL WEEVIL.

Figs. 52, 53, Mexican cotton boll-weevil (*Anthonomus grandis*), much enlarged (redrawn, after Hunter); fig. 54, *Lixus* sp., enlarged 3½ times (original); fig. 55, acorn weevil (*Balaninus uniformis* auct.): *a*, female, dorsal view; *b*, same, lateral view; *c*, head, snout, and antenna of male—all enlarged 4 times (from Chittenden, unpublished); fig. 56, apple curculio (*Coccotorus scutellaris*), enlarged (from Insect Life); fig. 57, plum gouger (*Anthonomus prunicida*), enlarged (from Insect Life); fig. 58, *Desmoris scapalis*, enlarged (original).

observed by Mr. E. A. Schwarz in the winter of 1901–2, weevils may pass the winter in either larval, pupal, or adult stages, but the last named is by far the most common stage.

It is likely that a large part of the weevils found in the squares and bolls during the first part of the winter will be in the larval stage, while, owing to the slow development which takes place, a larger percentage of adults will be found toward spring. Mr. J. D. Mitchell, of Victoria, Tex., took a number of live larvæ, pupæ, and adults from bolls in a field in that locality on December 26, 1903, after "two hard frosts and one freeze." Two weeks later, from a field at the same locality, after three hard frosts and two freezes, he took another lot of live specimens in these three stages. In the latter case the bolls examined were on stalks which had been plowed out two weeks before and were ready for burning at the time examined. Mr. Mitchell, who is an excellent and reliable observer, writes: "On December 26, there was still some sap in the cotton stalks," and on January 10, when the second examination was made, "there was absolutely none." "The larvæ seem to thrive and arrive at perfection in the dead and dried bolls. A frost or freeze at 30° F. does not hurt the larvæ or pupæ in dead bolls in the field." As the two lots, taken together with four others sent January 17, 31, and February 7 and 14, 1904, include 197 specimens (23 larvæ, 30 pupæ, and 144 adults) it is evident that large numbers of weevils go into the winter in the immature stages, and there is every probability that, in the southern part of the State at least, many of them live and mature, emerging in the spring. It may be that this gradual maturity of the hibernated weevils is one of the reasons why they emerge so irregularly from their winter quarters. Not all weevils go into hibernation at the same time, but as the mean average temperature falls to between 55° and 60° F. they gradually cease feeding, and, numbed and sluggish, they crawl into almost any place which furnishes them some measure of protection from the cold. Hibernating weevils are therefore to be found in many situations in the field. Where the cotton stalks are allowed to stand throughout the winter they furnish the weevils both the means of subsistence late in the fall and an abundance of favorable hibernation places throughout the field. The prospects of successful hibernation are thereby multiplied many times; and, furthermore, the weevils are already distributed over the field when they first become active in the spring. The grass and weeds which almost invariably abound along fence lines are exceedingly favorable to the successful hibernation of many weevils, so that it will be found generally true that the worst line of infestation in the spring proceeds from the outer edges of the field inward. Where cotton and corn are grown in adjacent fields, or where, as is sometimes the case, the two are more or less mixed in the same field, many weevils find favorable shelter in the husks and stalks of the corn. An especially favored place is said to be in the longitudinal groove in the stalk and within the shelter of the clasping base of the leaf. Perhaps the most favorable of all hibernating conditions are to be found among the leaves and rubbish abounding in the edges of timber adjoining cotton fields. From such places the weevils are known to come in large numbers in the spring. The timber fringes present greater difficulties in the way of removing the favorable conditions than do any of the other places mentioned.

Temperature and available food supply seem to be the most important factors in determining the time of hibernation. In general, it may be said that many weevils are active so long as their food continues in fit condition to sustain them. Some, however, undoubtedly seek shelter before frosts occur. From numerous observations made in the laboratory, it appears that weevils will starve when deprived of cotton if the mean average temperature continues long above a point somewhere between 60° and 65° F. As the mean average falls below 60° hibernation may take place successfully.

It is a very significant fact that of the 240 weevils taken from the field at the middle of December, 1902, and placed in hibernation, 38, or 15 8 per cent, passed the winter successfully, while of the 116 weevils adult before November 15, 1903, only 1, or less than 1 per cent, survived. It is evident that the weevils which pass the winter and attack the crop of the following season are among those developed latest in the fall and which, in consequence of that fact, have not exhausted their vitality by oviposition or any considerable length of active life.

LENGTH OF HIBERNATION PERIOD.

As the observations upon this point have all been made at Victoria, Tex., the statements made refer especially to that locality. It must be borne in mind that latitude and altitude, as well as seasonal variations, will influence the limits of this period. In general, however, it may be said that hibernation begins at about the time of the first hard frost, and that it continues until the mean average temperature has been for some time above 60° F. In the spring of 1903 weevils left hibernation quarters at Victoria only when the mean average temperature had been for some time at about 68° F. While it is true that weevils if disturbed in hibernation are active at much lower temperatures than this, for some reason they do not leave the shelter of their hibernation places.

At Victoria, Tex., the average hibernation season may be said to extend from about December 1 to about April 1, or a period of about 4 months. In more northern latitudes hibernation will, as a rule, begin earlier and last later, covering a period of from 4 to 5 months.

APPARENTLY FAVORABLE CONDITIONS FOR HIBERNATION.

In December, 1902, a series of experiments was started to test the influence of various conditions upon the successful hibernation of weevils. Owing to the writer's absence from Victoria examinations could not be made at intervals, as would have been desirable. But at the middle of April, 1903, careful examinations were made to ascertain the shelter in which live weevils were found. In the preparation of hibernation jars several inches of dirt was placed at the bottom, and above that a variety of such rubbish as was thought might tempt the weevils to shelter. Dead banana leaves, hay, cotton leaves, dry bolls, squares, etc., were among the things used as rubbish. As several of these were placed in each jar the weevils had an opportunity to choose their shelter. Among the 39 which lived through the winter, 19 were found in the banana leaves, 7 in hay, 5 in dry cotton leaves, 4 were buried in dirt, 3 were on the surface of the soil, and 1 was hiding in an open boll. It appears, therefore, that 31, or 80 per cent of the 39 live weevils, were found in what may be termed "leaf rubbish." It was noted also that 25 of the survivors passed the winter out of doors in various locations, while 13 were under shelter indoors. Of the weevils placed out of doors all but one lot were protected from the rain. The 15 weevils contained in the jar which became wet all died, while but few of the jars which were dry failed to show a live weevil in the spring. Leaf rubbish and dryness appear to be favorable factors in successful hibernation.

PERCENTAGE OF WEEVILS HIBERNATING SUCCESSFULLY.

Naturally the percentage of weevils living through the winter will depend largely upon favorable climatic conditions and the accessibility of suitable shelter. It would be utterly impossible to determine this question under actual outdoor conditions, and our inferences must be drawn solely from percentages found to survive under cage conditions. In the laboratory tests referred to in the preceding topic 356 weevils were used. Of these, 240 were brought from the fields at the middle of December, 1902. Among these weevils, 38, or 15.8 per cent, survived. The remaining 116 weevils were all adult after September 25, 1902, and had been kept under observation in the laboratory. One single weevil, adult November 12, was the sole survivor of this lot. Since the weevils brought from the fields in the middle of December would be a correct average of those entering hibernating conditions, we may disregard the laboratory specimens in drawing our conclusions. The conditions offered would seem to have been favorable, and when this is the case out of doors it appears that about one in six of weevils found in the field at hibernation time may pass the winter successfully. This seems a very high percentage, but when we consider the numbers of hibernating weevils often occurring upon young cotton in the spring it seems not improbable that during favorable seasons something like this percentage of the weevils finding favorable shelter will live. Of course, the percentage finding favorable shelter will be extremely variable, and it is in reducing the number and accessibility of favorable locations that the cotton planter has one of his very best opportunities to effect the destruction of a multitude of weevils, and thus greatly reduce the number which will emerge from hibernation and attack the crop of the following season. With shelter removed, cold and changeable weather will inevitably destroy many, and, in fact, most, of the weevils which would otherwise survive.

SEASONAL HISTORY.

EMERGENCE FROM HIBERNATION.

Emergence depends largely, as has been already shown, upon the mean average temperature prevailing. The presence of food does not seem to affect it. In the season of 1903 for one month preceding the emergence of weevils at Victoria the mean average temperature was 65.4° F. For the first two weeks of April it averaged 68.4° F. Weevils left their winter quarters from the middle to the last of April. While the mean average temperature for May was nearly 3° lower than the temperature prevailing at the time of emergence, weevils remained actively at work in the fields. In the fall also weevils remained at work at a lower temperature than that which seems to be necessary to draw them from their winter quarters. The reason for this fact is not apparent, but it is certain that once having left hibernation weevils will remain active at considerably lower temperatures. If the temperature becomes too low they remain quiet without taking food for long periods of time. If taken from their winter quarters weevils will be found active at ordinary day temperatures long before they would normally venture from their hiding places of their own accord. Weevils thus removed have been kept for a month without food or water, and they then assumed their normal activities when food was supplied to them.

After considerable search at San Diego in the spring of 1895, on April 27 Mr. Schwarz found the first specimens working upon seppa plants from roots which were then 2 years old. As the weevils first appeared in that locality in August, 1894, the number of hibernating weevils could not have been as great as in succeeding years, and consequently in the spring of 1895 hibernated specimens were "exceedingly rare." At Victoria, Tex., in the spring of 1902, Mr. Schwarz found the first weevils working upon volunteer plants on April 15. In the same locality the writer found, in 1903, that weevils left their winter quarters between April 10 and May 1. Evidence was found indicating that in some fields they began to move as early as March 28. At Calvert, Tex., also in 1903, Mr. Harris found the first weevils working on cotton on April 12. At Victoria, in 1904, weevils were found in numbers upon seppa plants on March 14 and they were found moving in the field at intervals throughout the winter.

From these observations it appears that normal emergence takes place usually some time in April, whether the first or the last of the month depending largely upon the earliness of the season. Furthermore, the emergence of the first weevils may take place from two to four weeks before that of the last. In this fact lies one of the two great obstacles which prevent the successful application of poisons to the early cotton as a means of destroying the weevils. The second obstacle is explained on pages 41–43.

Owing to the empty condition of the alimentary canal, hibernated weevils are able to fly with ease, and this they must do in their search for food. Doubtless many perish soon after emergence, even if they find food which many others never succeed in reaching.

APPARENT DEPENDENCE OF REPRODUCTION UPON FOOD OBTAINED FROM SQUARES.

During the fall of 1902 a series of experiments, lasting for 12 weeks, was made to determine the length of life of weevils fed solely upon leaves. In one lot, consisting of 9 males and 8 females, the average length of life of the females was 25 days, while that of the males was 36 days. Though this period far exceeded the normal time usually passed between the emergence of adults and the beginning of egg deposition, no eggs were found. Dissection of the females which lived longest showed that their ovaries were still in latent condition, though the weevils were then 81 days old. Few instances of copulation were observed among weevils fed upon leaves alone, and among nearly 70 weevils which were thus tested, no eggs were ever deposited. After a period of 3 weeks upon leaves, 11 weevils were transferred to squares. Females in this lot began to lay in 4 days, and 4 of them deposited 323 eggs in an average time of 20 days. The conclusion seems plain that so long as leaves alone are fed upon eggs do not develop, while a diet of squares leads to the development of eggs in about 4 days. It is worthy of note that the interval between the first feeding upon squares and the deposition of the first eggs is almost the same with these weevils taken in middle life as with weevils which have just emerged.

An examination of hibernated females taken in the spring of 1903, which had fed for 6 weeks upon cotton leaves, showed that their ovaries were still latent. Copulation was rarely observed among hibernated weevils until after squares had been given them. In a few days after feeding upon squares, mating and oviposition began. The average period was from 3 to 5 days, and having once begun, oviposition continued regularly.

It has been found that food passes the alimentary canal in less than

24 hours. Assimilation, therefore, must be very rapid. It is evident that while leaves will sustain life certain nutritive elements found only in squares are essential in the production of eggs.

Upon dissecting weevils just taken from hibernation it was found that females contained no developed eggs, but that their ovaries were in an inactive condition, similar to those of females which had fed for months entirely upon leaves during the previous fall. Upon examining females taken from seppa cotton later in the spring, but before squares had appeared, it was found that they also were in similar condition. This was also true of females kept in the laboratory from the time of emergence from hibernation until squares became abundant, with only leaves for food. It seems peculiar that upon a purely leaf diet eggs are not developed, but all observations made indicate that this is the case. It can not be said definitely whether the females examined had been fertilized, but it is certain that they were not ready to deposit eggs.

PROGRESS OF INFESTATION IN FIELDS.

From among the many notes made upon this point the results of the study of two fields are here presented. The first field, consisting of about 15 acres, had been planted in cotton for several years and was closely surrounded by other cotton fields. The second field of 35 acres was upon newly broken land and situated in a comparatively isolated location.

Examinations were made frequently to determine approximately the percentage of infested squares present in various parts of these fields. The conditions of the examinations were made as uniform as was possible. The fields were divided into blocks, and practically the same ground was covered in each block upon succeeding examinations.

TABLE XXII.—*Progress of infestation, field 1.*

Block.	Date.	Number of squares examined.	Number of squares infested.	Percentage.	Remarks.
	1903.				
I	June 8, 9	4,200	675	16.0	Work of hibernated weevils only.
	July 13	467	211	45.0	Second generation at work.
	July 22	249	193	77.5	Third generation beginning.
	August 4	278	224	80.6	
	August 29	91	85	93.5	About four generations now working.
II	July 30	358	168	46.6	Much cotton dying from root rot.
	August 1	331	148	44.7	
	August 4	300	100	33.3	
	August 20	699	636	91.1	
	Total	6,973	2,440	35.0	

The observations made in Block I cover a longer period, and are, therefore, more suggestive than those made in Block II. Evidently infestation began with the first appearance of squares. So long as the hibernated weevils alone were at work the percentage did not increase very rapidly, but with the advent of the second generation a much larger proportion of the squares became infested. Corresponding increases are seen with the third generation, but from that time on so large a proportion of the squares was infested that the percentage did not increase so rapidly. It may be noted in each block that the maximum percentage of infestation is slightly over 90. Some clean squares may always be found, however numerous the weevils may be, but those which escape weevil puncture are mostly less than half grown, so that while the percentage varies but slightly, few of these clean squares would escape the later attacks of the weevils and form blooms. In Block I the infestation was quite general. The situation of the block was especially favorable to the hibernation of a large number of weevils. Bounded on one side by a fence row, on the opposite side by a cornfield, and at one end by the buildings used by the tenant, an abundance of hibernating places was afforded the weevils, and as a result they came into the field in the spring from all those directions (Pl. XIII, fig. 51). It was noticeable, however, that the portion of greatest infestation early in the season lay in the corner between the fence row and the buildings. From the fence row especially the weevils spread toward the center of the field.

The second field, as has been stated, was comparatively isolated, so that infestation first began late in the season. Block I in this case lay in the corner between cross-roads. Block II adjoined the road farther on, while the third block was taken as far from these two as was possible. Infestation began in the corner covered by Block I. In studying this block, lots 1, 2, and 3, as numbered in the table, were taken diagonally across the block, away from the corner. Block II was separated from Block I by corn, the ends of the rows being at the road which passed the point of original infestation. The lots in Block II were taken in their order at varying distances from the road. Block III was some distance from the others. In this case lot 1 was taken along the edge on the side toward the other blocks, while lot 2 was taken in the middle of the block.

TABLE XXIII.—*Progress of infestation, field 2.*

Block.	Lot.	Date.	Number of squares examined.	Number of squares infested.	Percentage of infestation.	Remarks.
		1903.				
I	1	August 6	225	45	20.0	Infestation began in this corner.
		August 22	414	351	84.8	Lot 2, in middle of Block I.
	2	August 6	210	12	5.7	
	3	do	200	0	0.0	Lot 3, opposite corner of block from lot 1.
		August 22	362	241	66.6	
II	1	August 13	185	62	33.5	Lot 1, near public road, passing lot 1 of Block I.
		August 24	180	156	86.7	
	2	August 13	202	31	15.3	
		August 24	136	105	77.2	
	3	August 13	150	9	6.0	
		August 24	200	130	65.0	
III	1	August 17	218	91	41.7	Edge of block.
		August 29	259	228	88.0	
		August 17	166	38	22.9	Middle of block.
		August 29	330	290	88.0	

From a study of Block I it is evident that infestation began some time in July, since when first found it was entirely restricted to a small area. A study of each block chronologically shows the steady but rapid progress of the weevil, as does also a comparison of the three blocks at the nearest possible dates. The tremendous activity of weevils in midsummer and the possible rapidity of their spread is clearly shown in this field.

A study of two other fields yielded practically similar results. The dates of examinations, with the percentages found in each case, will be given. In field 3 there was found, upon June 2, 3 per cent of infestation; on July 16, 25.9 per cent; on August 15, 65.9 per cent. This field was from native seed and was planted about three weeks earlier than field 4, which was of King seed, and just across a turn row from field 3. In field 4 infestation began very late, as on August 8 there appeared to be only 2 per cent and on August 15, 23.6 per cent, while on August 26 it had increased to 91.5 per cent, which is about the usual percentage of maximum infestation.

Under the conditions usually prevailing cotton will cease to make when about two-thirds of the squares have become infested, since the weevils have then become sufficiently numerous to attack nearly all of the remaining clean squares before they have time to bloom and form bolls. Even bolls which have set before this percentage of infestation is reached are not entirely safe, as the smallest ones will be more readily attacked by weevils, as they have greater difficulty in finding uninfested squares.

WEEVIL INJURY vs. SQUARE PRODUCTION.

At the beginning of infestation the indications of the weevil's presence are inconspicuous. Even when considerably advanced most farmers do not recognize the injury, and thus are led to believe that the insect has not appeared. Among the most conspicuous indications of the weevil's presence may be mentioned the falling of infested squares. As the squares remain on the plant after they become infested fully as long as they lie upon the ground between the time of their falling and the emergence of the weevil, it is plain that less than half of the actually infested squares will ordinarily be observed. Previous to falling infested squares gradually turn yellow, and in most cases flare somewhat; but flaring is by no means as closely related to weevil injury as might be supposed. As the percentage of infestation increases the great numbers of squares on the ground must attract attention (Pl. XII, fig. 46). Shedding of squares may take place for other reasons than the attack of the weevil, but in fair weather, when large numbers of squares are found upon the ground, the weevil is probably present. As infestation approaches its climax there is a great decrease in the number of blooms, and when a field is found at blooming age with many squares, but no blooms, the weevils are almost certainly abundant. The conditions named form the most conspicuous indications of practically total infestation. During the season of 1903 it was found that a condition of total infestation was reached some time between August 1 and 20 in most fields within the infested area. This condition is, as a rule, coincident with the appearance in large numbers of weevils of the fourth generation. The exact time will vary in different seasons, and even in adjacent infested fields, because of varying conditions.

Not only is the maximum number of weevils present in the field in midsummer, but their capacity for injury is also greatest at that time. Practically all of the crop that will be made must have been set before this time. After this bolls will form only by accident.

A large series of examinations made by Messrs. Harris and Morrill at Calvert, Tex., shows the very rapid increase in the percentage of infested squares which usually takes place a few weeks earlier than it did in 1903. The figures given in each column in the table show also the closeness with which the weevil activity kept pace with the formation of squares after the period of maximum infestation had once been reached. The general influence of climatic conditions may be seen by a comparison of the last two columns in the table, but this point would be much more clearly shown by a series of examinations made during the first half of the growing season, at which time temperature and moisture would have greatest influence upon weevil development and injury. One hundred squares were picked promiscuously in each block for the determination of the percentages given in the columns for these 34 blocks, thus making a total of 17,000 squares examined.

TABLE XXIV.—*Study of the infestation of cotton fields at Calvert, Tex.*

Time of record.	Block.														
	1	2	3	4	5	6	7	8	9	10	11	12	20	21	22
1903.															
August 15-17	72	68	64	65	71	63	66	68	59	60	59	60	46	46	55
September 2-4	96	91	96	100	96	97	98	98	90	87	90	88	92	95	89
September 14-17	93	94	92	94	97	94	93	92	95	92	94	96	88	89	90
October 1-3	92	81	89	91	97	92	91	89	89	91	94	96	95	94	91
October 22-24	94	93	90	90	91	92	88	83	92	99	96	94	95	93	91

Time of record.	Block.														
	23	24	25	26	27	27 a	28	29	30	31	32	33	50	51	52
1903.															
August 15-17	48	50	54	47	49	52	54	58	54	54	57	55	62	66	58
September 2-4	69	94	91	91	88	93	95	91	91	93	93	97	89	94	96
September 14-17	92	91	92	94	93	92	90	96	94	96	93	94	93	92	95
October 1-3	94	94	90	96	93	94	92	92	95	99	94	96	92	87	86
October 22-24	95	91	89	98	94	91	97	90	97	95	97	93	96	97	97

TABLE XXIV.—*Study of the infestation of cotton fields at Calvert, Tex.*—Cont'd.

Time of record.	Block.				Average infestation for entire 34 blocks.	Climatic conditions.
	53	54	55	56		
					Per cent.	
August 15-17	64	69	67	62	58.88	Rainfall in July, 1903, 8.61 inches (or nearly four times normal rainfall); Aug. 1 to 15, nearly normal rainfall (0.79 inch, Aug. 2). Average temperature, July, 85° F.; Aug. 1 to 15, 85½° F.
September 2-4	89	94	90	97	91.41	Rainfall from Aug. 15 to Sept. 2, 0.9 inch (nearly normal). Average temperature, same period, 84½° F.
September 14-17	91	96	97	95	93.20	Rainfall from Sept. 2 to 14, 0.8 inch (about one-half normal). Average temperature, 83½° F.
October 1-3	78	92	88	89	91.56	Rainfall from Sept. 14 to Oct. 1, 0.14 inch (about one-tenth normal). Average temperature, 76⅝° F.
October 22-24	95	99	98	95	93.67	Rainfall from Oct. 1 to 22, 3.63 inches (more than two times normal). Average temperature, 74° F.

Still another series of observations made by Doctor Morrill, at Austin, Tex., shows that similar conditions prevailed in localities nearly 100 miles apart. For each of these percentages 300 squares were examined, thus making 14,400 observations in the series.

TABLE XXV.—*Study of the infestation of cotton fields at Austin, Tex.*

Time of record.	Block.											
	1	2	3	4	5	6	7	8	9	10	11	12
1903.												
August 4-7	29.0	34.0	11.0	15.0	10.0	9.0	19.0	33.0	43.0	43.0	36.0	31.0
September 7-9	95.3	95.0	95.3	96.7	92.7	87.3	95.0	96.7	96.7	96.7	95.3	93.7
October 5-7	90.3	88.0	90.3	90.0	94.7	85.3	92.0	92.0	96.0	96.0	92.7	96.0

Time of record.	Block.				Average infestation, entire 16 blocks.	Climatic conditions.
	13	14	15	16		
1903.					*Per cent.*	
August 4-7	33.0	36.0	49.0	55.0	30.37	July rainfall, 12.65 inches (above normal 10.35 inches). Mean average temperature, July, 82.6° F.
September 7-9	93.7	98.0	98.3	97.7	95.25	August rainfall, 0.79 inch (below normal 1.64 inch). Mean average temperature, 82.6° F.
October 5-7	92.0	89.3	92.7	92.7	91.87	September rainfall, trace (below normal 3.72 inches). Mean average temperature, 76° F.

As the first records at Austin were made about ten days earlier than were those at Calvert, they serve to show a much greater total increase in the average infestation during August, though the average daily increase in the percentage of infestation agrees very closely in the two localities, being 1.8 per cent at Calvert and 1.9 per cent at Austin.

A decrease in square production accompanies the maturity of the bulk of the crop, owing to the fact that the assimilative power of the plant is largely consumed in maturing seed. Dry weather normally occurring at this period also causes a decrease in the number of weevils present. Not only are there less squares to become infested, but each square is also subjected to greater injury, and many which would otherwise have produced weevils are unfitted as food for the larvæ by the decay which follows the numerous punctures. Several eggs may be deposited in one square, but as a rule only one weevil will result. At this season weevils turn their attention to young bolls upon which the injury previous to this time has been comparatively slight. It was found in one case that 35 or 40 per cent of the bolls were infested, while 15 per cent of the squares were yet clean. The longer period of development required by larvæ in bolls also serves to decrease the number of weevils produced. While the actual number of weevils begins to decrease within a short time after the period of maximum infestation is reached, the apparent numbers may possibly be greater. The decreased number of squares serves to concentrate the weevils upon those remaining, and therefore the number of weevils found in any square will be so much the greater.

RELATION OF WEEVILS TO "TOP CROP."

The hope of gathering a top crop is the "will-o'-the-wisp" of cotton planters. After considerable cotton has been matured fall rains often stimulate the production of a large number of squares, and many planters are misled by the hope of gathering a large top crop from this growth. The joints of the plant are short, and the squares are formed rapidly and near together. Though weevils may have been exceedingly numerous in the field, their numbers will have become so decreased in the manner described under the preceding heading that they can rarely keep up with the production of squares at this period of rapid growth. Many blooms may appear, and the hope of a large top crop increases.

The fact, however, as stated by prominent growers, is that before the appearance of the weevil they actually gathered only about three top crops in 25 years. The chance of its development, though always small, becomes hopeless wherever the weevil is present in considerable numbers. (See Tables XXIII, XXIV, and XXV, and average of infestation of entire fields, p. 88.) Neither the hopelessness of gathering a top crop nor the actual injury which is being done to the crop of the succeeding year by allowing that growth to continue until frost kills it is generally appreciated by planters. Because of the apparent abundance of squares and the presence of many blooms the plants are allowed to stand long after they might otherwise have been destroyed. As is the case in the early spring, however, the abundance of squares increases greatly the production of weevils; and though a few bolls may set, they are almost certain to become infested before they reach maturity. Every condition, therefore, contributes to the production of an immense number of weevils very late in the season and at just the right time for their successful hibernation. As the result of this, far greater injury is done to the crop of the following season, with a comparatively small gain in the yield of the present season. Furthermore, plants standing until frosts kill them are often allowed to stand throughout the remainder of the winter, and these furnish an abundance of favorable hibernating places for the weevils. The consequence of this practice is that so many weevils are carried through the winter alive that the yield of the next year will be much less than what it might have been but for the farmer's indulgence of the forlorn hope of a top crop.

From these considerations it seems plain that within the weevil territory all hope of a top crop must be given up and the destruction of the stalks be practiced as early in the fall as may be possible. This practice is one of the essential elements in the successful control of the weevil.

SOME REASONS FOR EARLY DESTRUCTION OF STALKS.

It is naturally impossible to fix any date for the destruction of stalks which would apply to all localities and under all conditions. The condition of the soil must be considered as well as that of the maturity of the crop. While the condition of the soil can not be changed, the time of the maturity of the crop is largely within the control of the planter, since by early planting of early maturing varieties nearly the entire yield may be matured before the usual time of picking of the first cotton from native seed. Whatever the qualifications which must be made, they do not decrease the general strength of the reasons which may be given for the early destruction of stalks. The principal reasons are three in number:

First, the absolute prevention of development of a multitude of weevils which would become adult within a few weeks of hibernation time. The destruction of the immature stages of weevils already present in infested squares is surely accomplished, while the further growth of squares which may become later infested is also prevented. This stops immediately the development of weevils which would normally hibernate successfully, and by decreasing the number of weevils which will emerge in the spring the chances of a good crop for the following season are greatly increased.

The second reason is that by a proper manipulation of the stalks a very great majority of the weevils which are already adult can be destroyed. One of the most successful practices is to throw the stalks in windrows, and as soon as they have become sufficiently dry they may be burned. If the weather is favorable, the burning may take place in about two weeks, and many of the weevils will not have left the cotton stalks by that time. In case rains delay the drying it will be found advantageous to expedite burning by the use of crude petroleum. Grazing the fields with cattle, as some have recommended, will destroy much of the growth and prevent further development of weevils, but it allows enough of foliage to remain to sustain the life of many which are already adult until it becomes sufficiently cold for them to hibernate. Not only does burning destroy most of the weevils, but it also destroys the shelter which might be afforded the few that would escape, and the chances of successful hibernation are largely decreased by this practice.

The third reason may be found in the fact that the clearing of the ground renders possible a deep fall plowing. This catches such weevils as might still be in squares on the ground. The ground becomes clean by this practice, so that no vestige of the food plant remains, and living weevils, if by any possibility they have escaped thus far, must either starve or perish from exposure. Furthermore, fall plowing places the ground in the best possible condition and makes it ready for immediate working as early as planting may begin in the spring, thereby saving delay in the starting of the crop. As stalks must be destroyed in some way before the field can be replanted, the practices here mentioned will not add greatly to the cost of destruction. Even if some cotton is present upon the stalks at the time of their destruction, this small item is hardly worthy of consideration in comparison with the greatly increased crop and the more early maturing and better quality of staple which may be obtained by the adoption of this recommendation.

Having studied carefully the methods of weevil control which have heretofore been recommended, the writers firmly believe that *the destruction of the stalks in the early fall is the most effective method known of actually reducing the numbers of the weevil.* Early destruction will cost but a small fraction of the expense necessary to the frequent picking up of the squares infested by hibernated weevils in the spring, and is far more thorough as a means of reducing the numbers of the weevil than is the practice of picking hibernated weevils from the young plants.

Early destruction of the stalks is essential to the greatest success of any system of controlling this pest. All other practices recommended—early planting of early maturing varieties, thorough cultivation, fertilization, etc. (see p. 112)—though very valuable in securing the crop, are perhaps of greatest value because they prepare the way for this early destruction which so reduces the actual number of weevils hibernating successfully that the other recommendations may yield their best results. Since the earliest investigations made by this Division upon the boll weevil, it has been recognized that this practice is of the first importance, and the experience of recent years has but added certainty to this conviction. Planters have, however, been slow to change their methods of cultivation, but enough have adopted the recommendation to prove its efficiency. It must not be thought that the procuring of the *immediate crop* is the only desideratum. *Early and complete destruction of stalks is undoubtedly the most important single element insuring success for the subsequent year.*

DISSEMINATION.

Two principal periods of dissemination may be found during a season. The first is when the hibernated weevils leave their winter quarters and go in search of food. Having found food, the spread is mainly controlled by the limitation of the food supply. So long as an abundance of growing tips or of clean squares is near at hand weevils will not travel far, but when the condition of total infestation is reached the period of greatest dissemination is also attained.

In any given field dissemination takes place mainly by the short flights and crawling of the weevils. The search of the female for uninfested squares is the principal factor in their movement. Heavy winds seem to be of comparatively small importance, as weevils do not take flight readily at such times; but light, warm breezes, such as prevail throughout the coast country of Texas, undoubtedly tend to carry them in a general northerly direction, and the continuous equinoctial storms of the fall in Texas, occurring at the very time the pests are most active, have undoubtedly had a strong effect in the same direction.

The two principal lines of spread will be found along railways and water courses. Between localities separated by short distances, traffic along highways is probably the chief factor. The distance which a weevil may travel in flight has never been determined, but from a study of their habits of flight it would seem to be comparatively short. Floods and the motion of water along water courses frequently serve to distribute many weevils along the edge of high-water mark. As river valleys are largely devoted to cotton culture, this would seem to be no small factor in the transportation of the weevils.

Over longer distances the usual means of commercial traffic must be held responsible. Shipments of cotton, whether for ginning or in baled condition, are likely to carry many weevils. Shipments of seed for planting, coming from infested localities, are almost certain to carry weevils, and shipments of seed to oil mills may also assist in scattering them. The pests are often carried far outside of infested regions in the shipment of seed to northern oil mills. From the mills they are carried to the farms in the hulls or other by-products used for feeding cattle. Many of the isolated colonies in northern Texas originated in this manner.

WEEVILS IN SEED HOUSES AT GINNERIES.

Careful observations made by Mr. Schwarz at Victoria throughout the winter of 1901–2 revealed great numbers of weevils about the gins. They occurred especially in the seed houses, and the danger of the transportation of the pests from one locality to another was most evident.

A casual examination of the dirt separators which are now in use in the more modern ginneries shows that immense numbers of weevils brought in from the fields are separated from the lint by these devices. Even where these separators are used, however, a short search in the seed house will show that many weevils pass through alive. A single hour's search in the seed house of a first-class ginnery, where dirt separators are in use, yielded seven boll weevils in perfect condition, and a number of other and much larger insects. In addition to these a number of fairly large spiders, most of which were in perfect condition, were also found. Numerous pupæ may pass through the gins unharmed in the cells formed by the larvæ. These cells are similar, both in size and shape, to the seed, and may often be mistaken therefor (Pl. XI., fig. 44). Distribution of weevils in seed is therefore easily possible, and uninfested localities should guard carefully against importing weevils in this way.

The most valuable suggestion for reducing the important effect that gins have in spreading the weevil is in the improvement of the cleaning devices referred to above, and in encouraging their more general use. A particular study of this matter will be made during the season of 1904.

NATURAL CONTROL.

Doubtless many factors are concerned in the natural control of the boll weevil. The most important ones are probably included among the following topics:

MECHANICAL CONTROL.

PILOSE OBSTACLES TO WEEVIL PROGRESS.

In testing the susceptibility of various cottons to weevil injury it was found that the variety of Egyptian cotton grown (Mit Afifi) was more severely injured than was any other. The next in order were Sea Island and Cuban tree cotton, while the American cottons, represented especially by King's Improved, were less severely injured than were any of the others. It may be noted that the three varieties first mentioned seem more closely related to each other than any of them do to the American. The reason for the evident choice of these cottons was carefully sought for, but the only difference which seemed worthy of consideration was found in the varying degree of pilosity upon the stems (Pl. XIII, fig. 50). It was found that Egyptian stems were almost perfectly smooth, while Sea Island and Cuban resembled it closely in that respect. Many American cottons, and King's Improved especially, are quite pilose, and it was often noted that upon these weevils showed some slight difficulty in moving about or in climbing the pilose stems of the plant. While this obstacle to weevil activity may seem slight to account for the evident selection of the smoother varieties, no greater difference could be found. As is shown by Table XI, on page 46, the selection is not due to a difference in taste of the squares.

In order to test the resistance which varying degrees of pilosity might offer to weevil progress, a number of experiments were made with various stems or fruits. In climbing upon the stems of King plants weevils would catch the spines with the forefeet while pushing themselves upward by means of the tibial spurs of the hind legs placed against the epidermis and between the spines. It was evident that their progress was considerably hindered, and several attempts were often made before a firm foothold was secured.

Okra pods were next tried, as upon them the spines are very short and stiff. Weevils climbed these pods with little difficulty.

The seed pods of Sunset Hibiscus were also tested. The spines upon these are from 2 to 3 millimeters long; they stand thickly and are quite stiff. Over these spines weevils walked easily, but though they attempted vigorously to get their heads down between the spines far enough to feed, they were unable to do so. A number of weevils were kept for several days upon these pods, but they were unable to feed. The spines were then removed from a small area, and the insects began to feed immediately.

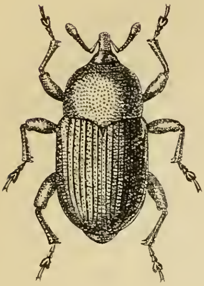
Weevils travel with difficulty over loose cotton fibers, as their feet become entangled among them.

DESTRUCTION OF LARVÆ AND PUPÆ IN BOLLS AND SQUARES BY ABNORMAL PLANT GROWTH.

In making examination of several thousands of infested squares a small percentage was found in which the larvæ had evidently been killed by an abnormal condition of the interior, which may be characterized as a process of gelatinization. This change begins at the point of injury and spreads. Instead of the normal growth of the anthers there takes place a change which appears to be something like the swelling of starch granules. The interior becomes soft and pulpy, and by the swelling considerable internal pressure is produced. The death of the larvæ results either from unfavorable food conditions or from the internal pressure, which in many cases is sufficient to distort the square. Whether from these or other causes, from 10 to 20 per cent of the larvæ usually die within the squares.

Gelatinization sometimes occurs in small bolls, but more rarely as bolls become larger and more mature. In large bolls in which seeds are nearly matured the feeding of the weevil larvæ often causes seeds to sprout, and in several such cases pupæ have been found crushed by the rapid growth of the caulicle.

In examining nearly 1,000 bolls, taken partly from King and partly from native cotton, it was found that in the early maturing King the



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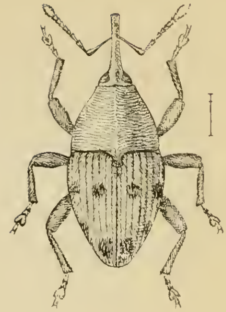

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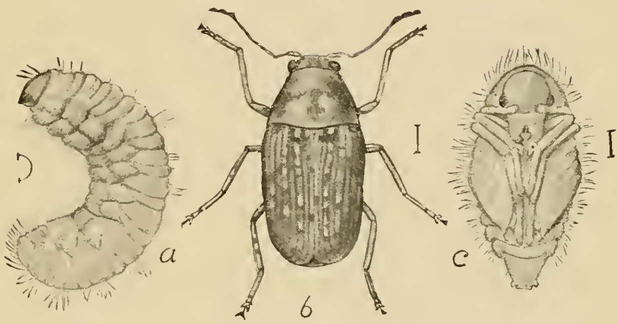


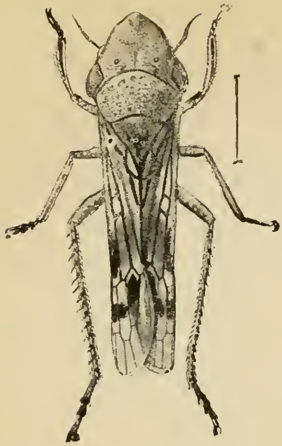
62

63

64

INSECTS OFTEN MISTAKEN FOR THE BOLL WEEVIL.

Figs. 59, 60, Transverse Baris (*Baris transversa*), much enlarged (original); fig. 61, *Centrinus penicellus*, enlarged (original); fig. 62, coffee-bean weevil (*Araecerus fasciculatus*): *a*, larva; *b*, beetle; *c*, pupa, enlarged (from Chittenden); figs. 63, 64, *Chalcodermus æneus*, enlarged (from Chittenden).



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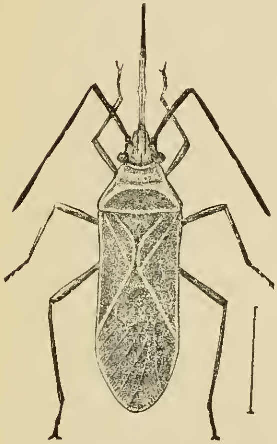

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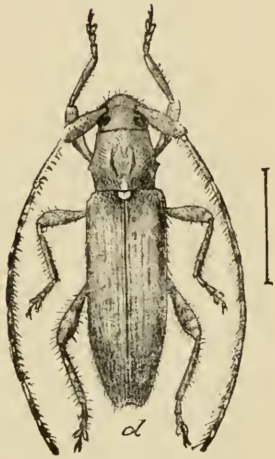

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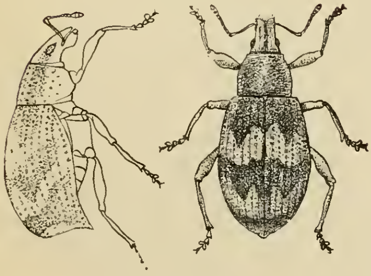

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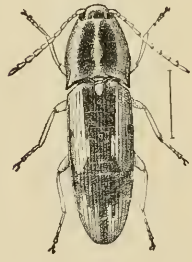

70

INSECTS OFTEN MISTAKEN FOR THE BOLL WEEVIL.

Figs. 65, 66, Sharpshooter (*Homalodisca triquetra*), enlarged (from Insect Life); fig. 67, cotton stainer (*Dysdercus suturellus*), enlarged (from Insect Life); fig. 68, cotton stalk borer (*Ataxia crypta*), enlarged (from Howard); fig. 69, imbricated snout beetle (*Epicærus imbricatus*), enlarged (from Chittenden); fig. 70, snapping beetle (*Monocrepidius vespertinus*), enlarged (from Chittenden).

percentage of larvæ and pupæ killed was much larger than in the native. In native cotton about 20 per cent of the larvæ were found to be dead, while in the King 41.2 per cent were dead. In all probability the more rapid flow of sap in the early developing King cotton was largely responsible for the changes which led to the death of the larvæ.

CLIMATIC CONTROL.

INFLUENCE OF CLIMATIC CONDITIONS UPON WEEVIL MULTIPLICATION AND INJURY.

Three principal factors affect the development, spread, and destructiveness of the boll weevil—temperature, precipitation, and food supply. So perfectly has the weevil become adapted to its single food plant that it is a very noticeable fact that the climatic conditions which are most favorable to the growth of the plant are most favorable also for the normal activities and development of the weevil. Affecting one in the same direction as the other, the pest is, therefore, enabled to very closely keep pace with its food supply under all kinds of natural conditions.

The most favorable conditions for the weevil are a high temperature and abundant moisture throughout a long season. These conditions favor the growth of the plant and produce a very large number of squares, which supply abundant opportunity for the rapid multiplication of the weevils. Severe drought checks together the growth of the plant and the development of the weevils. It has not yet been determined whether the death of larvæ in fallen squares exposed directly to the rays of the sun is due principally to the heat produced or to the complete drying of the food supply. It is certain, however, that one or both of these factors produce a large mortality among the larvæ and pupæ so exposed during long-continued hot and dry weather occurring before the plants have become large enough to shade most of the ground. After that the shade produced prevents most of the good work of the sun in destroying weevils.

It is often said by cotton growers that "rain brings the weevils." The principal reasons for this idea are that rains, in squaring time especially, produce conditions greatly favoring the immediate development and subsequent injury of weevils, while at the same time they make more apparent the amount of injury already done. An abundance of rain following a long dry period naturally causes great numbers of squares to fall from purely physiological causes, while at the same time it knocks to the ground such previously infested squares as have become weakened in their connection with the plant and which would fall naturally within a few days. The large number of squares to be found on the ground immediately after a storm would seem to account for the prevalence of the opinion mentioned. A large degree of moisture in fallen squares seems to favor directly the growth of larvæ within, thus producing quickly a large number of weevils ready to do further injury.

It is still an open question as to how low winter temperatures the weevil can withstand. It is certain that in southern Texas many larvæ and pupæ slowly continue their development during the winter season. Mr. S. G. Borden, of Sharpsburg, Tex., in a letter written January 27, 1896, says: "Hands clearing up cotton stalks report plenty of the larvæ in dry bolls." Mr. Schwarz found weevils hibernating in all stages, except the egg, at Victoria, Tex., during February, 1902. At the same locality in January and February of 1904, the weevils in larval, pupal, and adult stages were taken alive from dry bolls by Mr. J. D. Mitchell, a resident and cotton planter of that place.

After the weevils first made their appearance at San Antonio in the fall of 1895 they were supposed to have been entirely destroyed by frosts during the following winter. The lowest temperature recorded at San Antonio for that winter was 26° F. on December 30, 1895. On January 2, 1896, Professor Townsend made an examination of the condition of the weevil, and, so far as he found, all larvæ in bolls were then dead, while pupæ and adults were all alive. In spite of the mildness of the remainder of the winter the weevils did no damage to the crop of 1896, and were not found in fields in which they were present the year before. In writing of this unexpected condition, on October 19, 1896, Professor Townsend says, "The timely drought of last of May and first of June is what killed the weevils this year." There is therefore some doubt as to whether frosts or drought were responsible for the destruction of the weevils at San Antonio in 1896.

At Victoria, on February 17, 1903, the lowest temperature recorded by the Weather Bureau report was 20° F., but many weevils hibernated successfully. Doubtless much lower temperatures than this were experienced in more northern localities in the weevil belt, but in no place have the weevils been exterminated thereby.

EFFECT OF RAINS UPON DEVELOPMENT OF WEEVILS.

While it is a mistaken idea that rains first bring the weevils, it is true that they favor weevil increase in several ways. Frequent rains increase the growth of the plant and lead to the production of a larger number of squares which may become infested. Driving rains knock off infested squares, and by softening and moistening the food hasten the development of the larvæ within. Squares which are already upon the ground are protected during rainy weather from sunshine and drying. Rain hinders the enemies of the weevil far more than it does the development of the weevils themselves. In several such ways rains contribute directly or indirectly to the more rapid multiplication of weevils and cause the common impression among cotton planters alluded to above.

EFFECT OF WET WINTER WEATHER ON HIBERNATING WEEVILS.

Owing to the writers' absence from Victoria during the winter months, observations could not be made directly or immediately upon this point. It was found, however, that all weevils in hibernation tests which passed the winter successfully had been kept dry. The winter of 1902–3 was unusually wet at Victoria, and the number of hibernated weevils which were to be found on early cotton plants was noticeably less than during previous seasons which had been dry. It seems probable, therefore, that as many weevils perish from frequent wetting as from exposure to the cold.

EFFECTS OF OVERFLOWS IN FIELDS.

Unusually favorable conditions for these observations were obtained at Victoria in the season of 1903. During the latter part of February an overflow of the Guadalupe River covered many of the cotton fields along its course. The fields in which especial study was made were wholly submerged from one to several days. Cotton was planted in some of these fields between March 15 and 17. Owing to cold weather the growth of the plants was delayed and squaring did not begin until between May 10 and 17. Immediately after this date it was found that weevils were present and at work, and fallen squares were first found about May 23. From a study of this field it became apparent that the overflow had caused a considerably less decrease than had been anticipated in the number of hibernating weevils. Possibly the fact that the winter of 1902–3 had been exceptionally rainy may account for the lack of contrast in weevil abundance in overflowed fields and those which did not suffer in this way since, as has already been noted, hibernated weevils were unusually scarce, even on uplands.

Another period of high water occurred during the last of June and the first of July and gave a convenient opportunity to note its effect upon active weevils. Many fields were partially and some wholly submerged. This condition lasted for several days. Examination made after the recession of the water showed that many fallen squares which had certainly been in the water for some time contained uninjured larvæ and pupæ. Naturally eggs and larvæ found in squares upon the plants, even though under water for some time, escaped unharmed. Weevils were working normally upon the plants. No diminution in their numbers could be seen and it was apparent that the overflow caused no check either to the development of the immature stages or to the activity of the adults. These observations emphasize the fact that the weevil can not be drowned out.

LABORATORY OBSERVATIONS UPON TIME WEEVILS WILL FLOAT OR ENDURE SUBMERGENCE.

These tests were divided into two parts, each of which includes both the immature and mature stages. In each part floating and submergence were tested.

Sixty squares, believed from external examination to be infested, were floated in a driving rain for six hours. They were then removed and left for several days, during which time 75 per cent of them produced normal adults. Ten squares which were floated in driving rain for six hours were opened at once, and in every case found to be but slightly wet upon the inside. These contained 6 larvæ and 4 pupæ, and all were in perfect condition.

As squares float normally, submergence tests were considered extreme. Five squares were submerged for six hours, and after that produced 3 normal adults; 1 pupa died, and 1 square was found to have been uninfested. Five more squares were submerged for thirty-one hours. These produced 2 normal adults, and 1 pupa died in the process of molting after removal from the square. Death was probably caused in the last case by drying; 1 square was found to contain a dead pupa, and 1 was not infested. To test the possibility of its living, should the square be penetrated by water, a naked pupa was submerged for six hours, but in spite of this unusual treatment it produced a normal adult.

In the tests made upon the floating power of adults, weevils were isolated and placed in water in tumblers. They were dropped from a considerable distance above the surface, so that they became entirely submerged, and then floated to the surface naturally. The surface tension of the water was found to be sufficient to float weevils which were placed upon it carefully. The generally hairy condition of the surface of the weevil's body prevents its being readily wetted, so that it may struggle for some time in the water without becoming really wet. When dropped in this way weevils float head downward, with the tip of the abdomen above the surface. In the submergence tests weevils were held down by a wire screen, and all bubbles were removed from their bodies by a pipette, thus making the tests as severe as possible.

TABLE XXVI—*Effects of floating and submergence on all stages.*

Conditions of test.	Time in test.	Dead at end of test.	Time before examination.	Normal adults after test.	Remarks.
	Hours.		*Days.*		
Sixty squares floated in rain.	6	--------	4 to 8	45	5 squares contained dead larvæ; 3 pupæ destroyed by ants, and 7 uninfested.
Ten squares floated in rain	6	None.	None.	--------	Squares but slightly wet inside. 6 larvæ and 5 pupæ all alive and normal.
Five squares submerged	6	--------	7 to 8	3	1 pupa dead; 1 square uninfested.
Do	31	1 pupa.	None.	2	1 pupa and 2 larvæ alive after test; squares not wet much inside.
One naked pupa submerged	6	0	--------	1	
Ten adults floated	25	0	--------	6	
Do	112	1	--------	2	6 recovered so as to feed, but 4 died in from 2 to 7 days; 1 lived 36 days and laid 58 eggs.
Five adults submerged	3	0	--------	3	
Do	15	2	--------	3	2 males died soon; females laid 43 eggs in 15 weevil-days.
Ten adults submerged	25	9	--------	0	1 lived through test, but never fed.
Fourteen adults submerged	48	14	--------	0	

In the case of squares floating normally it is evident that they might remain in water for several days without injury to the weevil within. Very slight wetting of the cell takes place even under the extreme conditions of submergence. The effect of a brief flood would not, therefore, be at all injurious. As adults float as readily as do squares, they may also be carried long distances, and, furthermore, they are able to crawl out of the water onto any bushes, weeds, or rubbish which they may touch. Even when floating for several days continuously they are able to live and may be carried directly to new fields. The floating of adults and infested squares explains the appearance of weevils in great numbers along high-water line immediately after a flood, and indicates that probably the most rapid advance the pest will make in the United States will be into the fertile cotton lands of the Red River Valley in Louisiana.

PROBABILITIES AS TO THE INFLUENCE OF CLIMATE ON THE WEEVIL IN COTTON REGIONS NOT NOW INFESTED.

The influence which the lower temperature prevailing over the northern edge of the cotton belt may have upon the development, destructiveness, and spread of the weevil is as yet largely problematical. No considerable amount of accurate data upon the development of the weevil being at present available except that collected at Victoria, Tex., during the seasons of 1902 and 1903, it is impossible to predict with certainty how far or how rapidly the weevil may spread or the rapidity of development which may take place under the different climatic conditions prevailing in regions not at present infested, or whether it may be expected that its destructiveness to cotton will be materially reduced in other sections. These questions are, however, of considerable interest because of the probability that the weevil will ultimately spread over the entire cotton belt in spite of any measures which may be adopted to retard its progress.

During the past century the attention of many botanists and zoologists has been drawn to the relations existing between geographic areas and the distribution of plants and animals. In this country the limits of the well-defined zones and the laws governing the distribution of plant and animal life through those zones have been most carefully determined by Dr. C. Hart Merriam, Chief of the Division of Biological Survey of the United States Department of Agriculture.[a] A few years before the publication of Doctor Merriam's completed results Dr. L. O. Howard, Chief of the Division of Entomology, first applied the principles underlying geographic distribution to a study of the probable spread of a number of species of very injurious insects, most of which had been imported into this country,[b] and recently he has made a more extensive study of a very practical nature concerning the geographic distribution of the yellow fever mosquito.[c] Many observations have shown that in general the limits of the spread of an imported insect pest may thus be approximately determined. It is, therefore, not out of place to consider at this time some points in regard to the probable status of the boll weevil in the cotton belt outside of Texas.

According to the map published by Doctor Merriam, the entire cotton-growing area of the United States lies within the Lower Austral Zone, the northern limit of which is marked by the isothermal line showing a sum of normal positive temperatures (above 32° F.) amounting to 18,000° F. The weevil has already become established near Sherman, Tex. As nearly as can be told from data at present available, the isothermal line passing through Sherman, if extended eastward, would pass along the Red River Valley, through the extreme southern part of Arkansas, across central Mississippi and Alabama, a little south of Atlanta, Ga., and thence curve northeastward through South and North Carolina. It therefore becomes evident that "temperature" will not prevent the spread of the weevil eastward. Even if it should not go beyond the isothermal line within which it now thrives, its territory would still include most of the great cotton belt of the United States. Furthermore, there is no evidence to show that the weevil has yet reached its most northern limit, and the probabilty remains that it may yet show itself capable of existing anywhere within the Lower Austral Zone where cotton can be grown.

A comparison of the positive temperatures of various localities in the

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[a] Bulletin 10, U. S. Dept. Agr., Division of Biological Survey, Life Zones and Crop Zones of the United States.

[b] Proc. Entom. Soc. Washington, Vol. III, No. 4, pp. 219-226. "Notes on the Geographic Distribution in the United States of Certain Insects Injurious to Cultivated Crops."

[c] Treasury Department—Public Health Reports, Vol. XVIII, No. 46. "Concerning the Geographic Distribution of the Yellow Fever Mosquito."

northeastern part of the cotton belt with that of Victoria, Tex., during the six months from June 1 to November 30, 1902, naturally reveals a considerable range of difference, as does also a comparison of the average temperatures prevailing in those localities during the same period for the preceding eleven years. Wherever it is considered in its effect upon the development of the weevil the temperature given is expressed in degrees of effective temperature—that is, the actual temperature above 43° F. The mean average effective temperature for any month multiplied by the number of days included has been considered as giving the total effective temperature for that month. While this method does not give exactly the correct figures, it will furnish data for a comparison of the various localities, and this study of temperatures will undoubtedly reveal facts which will exert considerable influence upon the status of the weevil in other localities into which it is liable to spread.

The total effective temperature for Victoria, Tex., from June 1 to November 30, 1902, was 6,607° F. For the same period at Dallas, Tex., it was 5,626° F., and at Atlanta, Ga., it was 5,052° F.

The average mean total effective temperatures for the sections of Texas, Louisiana, and Georgia, as given by the Weather Bureau for a series of eleven years, are as follows: Texas, 5,716°; Louisiana, 5,578°; Georgia, 5,234° F.

The effect of this decrease in temperature will doubtless be in some measure counteracted by a certain degree of adaptation thereto on the part of the weevil, but it still seems probable that in the temperature of Georgia a considerable reduction in the number of generations will be found. The emergence from winter quarters will probable be considerably later than the middle of April. The development of progeny will not be as rapid as has been described for Victoria, Tex., in preceding pages. Furthermore, it seems likely that during the warmest periods the life cycle will require from 22 to 28 days. The consequent limited number of generations in a season will be still further curtailed by the earlier period of hibernation, which it seems will begin as early as the latter part of October or the first of November, instead of during December, as was the case during the past two years at Victoria. The date of the killing frosts will, in a general way, fix the end of the active season for the weevil, and this will therefore vary considerably from year to year.

Table XXVII.—*Temperature comparisons of various cotton sections.*

Month.	Monthly average normal mean for 11 years, 1892-1902.						
	Victoria, Tex., average (1902 and 1903 only).	Dallas, Tex.	Shreveport, La.	Atlanta, Ga.	Texas section.	Louisiana section.	Georgia section.
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
June	75.0	80.5	79.9	78.0	80.6	80.1	78.2
July	80.8	83.3	82.4	80.3	88.9	83.5	80.1
August	80.2	82.8	82.5	79.2	82.8	81.6	79.0
September	77.6	77.4	77.8	70.2	77.3	77.1	74.7
October	71.6	68.1	67.1	62.6	67.9	67.7	64.5
November	63.7	56.7	56.8	57.8	57.3	58.9	58.9
Average for 6 months	74.8	74.8	74.4	71.2	74.6	74.6	72.2

From these considerations of temperature difference and judging the varying influence as ascertained at Victoria, it seems that the weevil may prove less and less destructive as it spreads to the cooler portions of the cotton belt, though this supposition is likely to be nullified by an ability to adapt itself to new conditions.

While it must be admitted that nothing, so far as now known, seems certain to prevent the spread of the weevil to any latitude where cotton is now grown, it does seem probable that its control may be more easily accomplished in the more northern portions of the cotton belt than in the Texas area now infested, and since it has been most positively demonstrated that better than the average crop may here be grown in spite of the depredations of the weevil, there would seem to be no special reason for a panic over the future of the cotton crop. Cotton has been and still will be grown in spite of the weevil. The present promise is that those planters who enter the struggle with determination, and who adopt the advanced methods which have proven successful wherever tried, will realize practically as large a profit from cotton raising in the future as it has been possible to obtain in the past.

DISEASES.

Especially in moist breeding jars, weevils often die from what appears to be a bacterial disease. The body contents liquefy, turning to a dark brown in color, and have a putrid odor. Death follows quickly, though not until after putrefaction has begun. The frequency with which several weevils died in the same jar at about the same time indicates that this disease may be contagious. It has not been found in the fields, however, and may have been due entirely to abnormal laboratory conditions.

It is doubtful whether the following observations upon fungus attacks upon weevils should properly be classed with diseases, but as there is a possibility that the attack may have been of this nature, the observations may be given here.

In July, 1902, a lot of squares sent by mail from Calvert, Tex., to Victoria, was so long delayed upon the road that they were very moldy when received. Thirteen apparently healthy pupæ were removed from these moldy squares with the intention of rearing the adults. The pupæ were kept moist, and in a short time 5 died, apparently from the attacks of an unknown species of fungus. The remainder were then kept dry, but in spite of this precaution 6 more died, only 2 becoming adult. In another lot of 27 pupæ, 5 died, apparently from attacks of the same fungus.

Specimens of the dead pupæ were sent to the pathologist of the Bureau of Plant Industry of the Department for determination of the fungus. It was pronounced to be a probably new species of *Aspergillus*. As no species of this genus is known to be parasitic, it may be that the pupæ died from some other cause and that the fungus was entirely saprophytic. The external appearance of the fungus so soon after the death of the pupæ, the large mortality prevailing, and the known fact that pupæ develop uninjured in the presence of many species of molds leads to the suspicion that it may have had some part in causing the death of the insects.

In 1894 Prof. C. H. T. Townsend, while engaged in the study of the boll weevil, found in a field at San Juan Allende, Mexico, a specimen of a dead pupa which had been attacked by a species of parasitic fungus (*Cordyceps* sp.). As no other cases of attack by this fungus have been reported, its occurrence is probably very rare.

PARASITES.

BREEDING OF PARASITES.

Owing to the importance attached to parasites in the control of many pests, considerable time has been devoted to the rearing of parasitic enemies of the boll weevil. From the very nature of the habits of the weevil, no perfectly satisfactory method of breeding these parasites could be devised. The apparatus used was exceedingly simple. Squares which were thought to be infested were picked or gathered in the field, and cleared, so far as was possible, of all that might produce parasites not developed from the weevils. Small lots of these squares were placed in paper bags, each fitting tightly over the open mouth of a glass jar. As both parasites and weevils upon emergence naturally make their way to the light, they could easily be seen in the glass jars and at once removed. Even when thus bred something must be known of the habits of each species of insect produced or of its close allies to determine whether it is really a parasite upon a weevil larva, a hyperparasite, or merely a vegetable feeder developed in the decaying square. Many small flies breed in such decaying matter and were caught in the jars, but these must all be acquitted of being parasites upon the weevil. The results are therefore made somewhat uncertain because of the impossibility of isolating the weevil larvæ. A condensed summary of the results in breeding parasites through two seasons' work is presented in Table XXVIII.

TABLE XXVIII.—*Breeding of parasites.*

Locality.	Collector.	Date.	Squares.	Weevils bred.	Parasites.	
					Bracon mellitor.	Other species.
Squares picked from plants and from ground.						
		1902.				
Calvert, Tex	G. H. Harris	July, August	2,566	277	3	1
Victoria, Tex	W. E. Hinds	do	645	210	1	1
Guadalupe, Tex	W. D. Hunter; W. E. Hinds	August	387	108	1	0
		1903.				
Victoria, Tex	W. E. Hinds	June	881	278	10	0
Do	do	July	264	111	3	1
Do	do	August	463	251	0	0
Infested squares dried on the plants.						
Victoria, Tex	W. E. Hinds	July, August	342	120	45	5
Total			5,548	1,355	63	8

From these observations it appears that 24.4 per cent of the 5,548 squares used produced adult weevils, while only 1.3 per cent of the total squares contained parasites. Among the parasites obtained, 90 per cent were of the single species *Bracon mellitor* Say (fig. 4). A single specimen of another undoubtedly primary parasite, *Sigalphus curculionis* Fitch, was reared. A few specimens of *Catolaccus incertus* Ashm. may possibly have come from the weevil larvæ, but were more likely hyperparasites. According to the authority of Dr. William H. Ashmead, of the United States National Museum, to whom the writer is indebted for the specific determinations and also for information about the usual habits of these parasitic insects, the following species, which were bred from squares, must probably be credited to some other host than the boll weevil: *Chalcis coloradensis* Cress. and *Goniozus platynotæ* Ashm. were probably upon lepidopterous larvæ; *Eurytoma* sp. and *Eupelmus*, two spp., usually attack dipterous larvæ in galls and a number of specimens of a species of *Ooencyrtus* may have been parasitic upon the eggs of some lepidopteron or hemipteron, but certainly could not have reached the eggs of the weevil.

FIG. 4.—*Bracon mellitor*, parasite of boll weevil—much enlarged (original).

It is very noticeable that the dried squares which were picked from the plants produced by far the largest part of all the parasites obtained, 342 squares giving 50 parasites. In this lot, therefore, 14 per cent of the total number contained parasites of some kind and 13 per cent were undoubtedly developed from the weevil larvæ. Taking all other squares together, 5,286 yielded only 18 primary parasites, or only 0.3 per cent.

Previous efforts to breed parasites of the weevil yielded as meager results as those which have just been recorded, though they add to the number of species. In 1894 Prof. C. H. T. Townsend bred, at Corpus Christi, Tex., a single specimen of *Urosigalphus robustus* Ashm., which was in all probability a primary parasite, as was also *Bracon dorsata* Say, of which Mr. Schwarz obtained two specimens at Goliad, Tex., in the fall of 1895. A specimen of *Eurytoma tylodermatis* Ashm., also reared by Mr. Townsend, may possibly have had some other host.

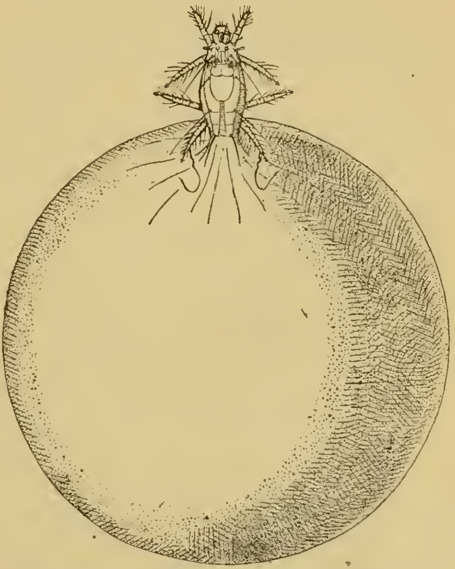

Fig. 5.—Enemy of cotton boll weevil, *Pediculoides ventricosus*—much enlarged (adapted from Brucker).

Pediculoides ventricosus Newp.—This small mite has been thought by some scientists to be the most promising parasite yet found attacking the weevil. It has been experimented with quite extensively by Prof. A. L. Herrera and his assistants of the Mexican Commission of Parasitology. The mites breed with extreme rapidity, the larvæ of wasps being their usual hosts. Both sexes attain full physical and sexual maturity while yet within the body of the mother. The males are exceedingly tiny, as are also the females, when they first leave the mother mite. As the females become gravid, however, their abdomens swell to an astonishing size as compared with the rest of the body, being distended by the rapid growth of the young mites (fig. 5). When these are born the mother dies, while the offspring mate, and then immediately begin the search for food. The idea of the Mexican investigators was that these tiny parasites would be able to enter the square through microscopic orifices in the outer layers, and that they would attack and destroy the weevil larvæ and pupæ within. Upon his return from a trip to Mexico in the fall of 1902, the senior author brought with him, through the kindness of Professor Herrera, a supply of the parasites, from which others were reared for experimental work in Texas.

In the course of these experiments the possibility of the mites attacking larvæ, pupæ, or immature adults was tested. The observations made failed to show any positive ability on the part of the Pediculoides to penetrate the squares, as in only two cases were mites found in them and attacking the larvæ. In these two cases it seems entirely possible that the mites may have entered through feeding punctures or some other rupture in the floral envelopes.

Upon several occasions during the season of 1903 mites were distributed in badly infested cotton fields. Later examinations were carefully made, but they failed to show that the parasites had gained a hold or even that they had attacked the weevils in any stage.

These mites, if, indeed, they are of the same species as those described by Newport, are widely distributed and attack, to some extent, quite a large number of insects. If they really possessed the ability to get at the weevil larvæ and the predisposition to attack them when they could get to them in preference to other hosts, they should certainly have shown something of these capabilities somewhere within the infested area in Texas during the ten years that the weevil has been found there. As no such ability has yet been shown, we doubt that the Pediculoides will ever prove of any value as a parasite of the weevil in the United States, though it may be more efficient in more southern countries. Furthermore, it is said that even where the mites do become established they are so subject to the attacks of small ants that their efficiency becomes largely destroyed.

Several attempts have been made by agents of this Division to breed parasites of the weevil in localities which must be much nearer its original home than is Texas, but thus far these attempts have proven as fruitless as have those made in Texas. It seems desirable that this work should be continued so as to give a more complete knowledge of all the parasites of the weevil in its native home.

These results show how insignificant is the part which insect parasites play in the problem of controlling the boll weevil in Texas. The thorough protection of all immature stages of the weevil by several layers of vegetable matter and the protection of the adult by its hard, closely fitting, chitinous, external plates renders very small the hope that any parasite will ever become an efficient factor in controlling this dangerous pest.

There is at present, therefore, no promise of any considerable assistance in the control of the weevil by any parasite now known. Because of its peculiar life history the weevil is unusually exempt from the attacks of parasites. Even should one be found which could attack the weevil in some stage, it would probably still fail to be an efficient means of control, because, from the very nature of its parasitic habits, it is bound to be behind the weevil both in the point of numbers and in the time of its activity. While such parasites might serve to decrease the numbers of the weevil, every larva that becomes parasitized has already done its damage to a square.

In spite of the present unpromising outlook for the discovery of valuable parasites of the weevil, every effort to find such should be made. While earnestly hoping that effective parasites may yet be discovered or developed, it is folly for planters to neglect or delay the adoption of those methods of decreasing weevil injury which have already proven to be both practical and effective.

PREDATORY ENEMIES.

INSECTS.

Insects which prey upon the boll weevil appear to be even fewer in number of species than are those which are parasitic upon it. The principal enemies of this class are ants, and where common these probably destroy more immature weevils than do the parasites. They are frequently to be found in squares on the ground in the act of destroying larvæ or more often pupæ. Occasionally they have been found entering infested bolls which are yet hanging upon the plants and destroying the pupæ, which had become exposed by the premature cracking open of their cells. In some cases they have been known to destroy young adults which had emerged but not become fully hardened. Several species of ants are concerned in this good work. The most active is a small red ant, *Solenopsis debilis* var. *texana* Mayer? (fig. 6). Another species belonging to the genus Myrmica also does considerable good.

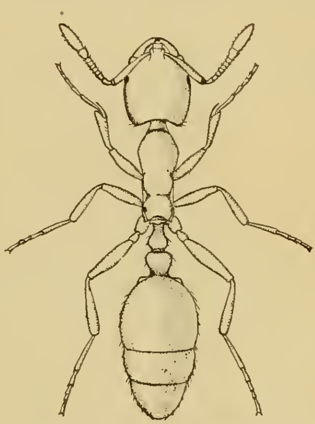

FIG. 6.—*Solenopsis debilis* var. *texana*? ant enemy of boll weevil—much enlarged (original).

Occasionally there may be seen upon cotton plants specimens of a mantis, or "devil horse," as it is more commonly called. One species only, *Stagmomantis limbata* Hahn., has been carefully tested for its ability to destroy weevils. A male of this species was confined in a breeding cage and supplied with a number of adult weevils. Several times it was seen to seize a weevil and attempt to eat it, but being unable to break through the hard chitinous plates which so closely cover the weevil's body, it gave up the attempt and let the weevil go unharmed. Although kept for some time with weevils in its cage, it never fed upon them, but starved to death in their presence. With the female of this species the case is quite different. One was confined in a cage and supplied with an abundance of weevils. It seemed to be more powerful than the male, breaking through the weevil's skeleton with apparent ease. On several occasions it was found to eat 8 or 10 weevils a day. During her period of confinement in the cage she deposited a large batch of eggs, and in the course of about three weeks she destroyed altogether a total of 80 weevils.

Some species of Mantispa also probably devour a few weevils in the field, but the writer has never seen one in the act.

BIRDS.

There can be no doubt that birds are exceedingly valuable assistants to man in reducing the numbers of many insect pests. In order to determine to what extent they feed upon the boll weevils, it is necessary that an extensive study be made of the stomach contents of all birds that may be found in cotton fields. To be at all conclusive such studies must be made in numerous localities and during more than one season. To accomplish this it is deemed advisable to reserve for the present the results of the study of the relation of birds to the weevil problem, that a more complete treatment of the question may be made in some future publication.

METHODS OF COMBATING THE WEEVIL.

The difficulties in the way of controlling the boll weevil lie as much in its habits and manner of work as in the peculiar industrial conditions involved in the production of the staple in the Southern States. The facts that the weevil lives in all stages except the imago within the fruit of the plant, well protected from any poisons that might be applied, and in that stage takes food normally only by inserting its snout within the substance of the plant; that it is remarkably free from parasites or diseases; that it frequently occupies but 14 days for development from egg to adult, and the progeny of a single pair in a season may reach 134,000,000 individuals; that it adapts itself to climatic conditions to the extent that the egg stage alone in November may occupy as much time as all the immature stages together in July or August, are factors that combine to make it one of the most difficult insects to control. It is consequently natural that all the investigations of the Division of Entomology have pointed toward the prime importance of cultural methods of controlling the pest. All other methods must involve some direct financial outlay for material or machinery, and are consequently not in accord with labor conditions involved in cotton production in the United States. Moreover, the cultural methods are in keeping with the general tendency of cotton culture; that is, to procure an early crop, and at the same time have the great advantage of avoiding damage by a large number of other destructive insects, especially the bollworm. Nevertheless, it must not be understood that attention has not been paid to the investigation of means looking toward the extermination of the pest. As a matter of fact, every suggestion, from the possibility of breeding resistant varieties to the use of electricity in destroying the weevil, has been fully investigated. The results have all been negative.

CULTURAL METHODS.

The cultural method begins with reducing the numbers of the pest in the fall by the destruction of the plants as soon as it becomes apparent that no more cotton is to be produced. The enormous importance of this procedure is shown by the fact already stated (p. 82) that the late issuing weevils are the ones which successfully hibernate. Further strong reasons are given on pages 91 and 92, under the sections "Relations of weevils to top crop" and "Some reasons for the early destruction of stalks." Hosts of weevils may thus be killed, a very small percentage surviving the winter, and in the same operation the ground is better prepared for planting the following season. A large proportion of the weevils thus destroyed would otherwise pass through the winter successfully and increase the damage to the planted cotton the following season. Wherever the cotton is allowed to stand in the fields in the hope that a top crop may be produced opportunities are furnished for the development of a very large number of weevils. As explained before in this bulletin, the possibility of a top crop has always been exceedingly remote. Wherever the weevil exists it is not a possibility at all. The method of fall destruction only involves applying labor that is necessary in any case in preparing the land for planting a few months earlier than is the normal practice among cotton planters. It has been the custom to leave the land uncleared until shortly before planting time in the spring. Now, however, this clearing process is necessary as the last step in the production of the preceding crop. This method, as a matter of fact, is the only practicable strictly remedial method that has been devised.

Simple uprooting of the plants by means of plows, and burning them as soon as sufficiently dry, is very effective; but undoubtedly the most effective way would be to leave a row out of 20 after the general uprooting has taken place, to serve as a trap. When the weevils have assembled upon these plants they might be killed easily with crude petroleum, as the destruction of the plants at that time would be immaterial. Nevertheless the heaps of drying stalks also act as a trap, and consequently, especially in view of the success that attends the method, the average planter will believe the destruction of all the plants in the field a better plan than any modification of it.

The remaining portion of the cultural method consists in furthering the advantage gained by fall destruction by bending every effort toward obtaining a crop that will mature before the weevils have had an opportunity to do considerable damage. The most important factors in obtaining an early crop are early planting, selection of a rapidly growing variety, fertilization, and thorough cultivation. The success of the planter will be in direct proportion to the extent to which he is able to combine these essentials. Early planting of early varieties will be found to be of comparatively little avail unless followed by thorough cultivation, and in case of unavoidably delayed planting the best hope of the planter will be in persistent cultivation.

As the details of the cultural method have been dealt with fully in the Farmers' Bulletins of this Department, and as the basis for them in the habits of the weevil was fully explained in the preceding pages, it is unnecessary in this connection to more than summarize them:

(1) Fall destruction.

(2) Early planting of rapidly maturing varieties.

(3) Wide spacing, which, besides favoring rapid maturity of the plant, also acts as a remedial measure by allowing the sun to reach the ground and causing the drying up of the squares in which the larvæ occur.

(4) Thorough cultivation.

(5) Fertilization with commercial preparations containing high percentage of phosphoric acid.

In addition to this general system that is applicable to all cotton plantations, favorable labor conditions sometimes make it feasible to pick the infested squares by hand. Nothing could be more out of place than to suggest hand picking upon large plantations. Even with convict labor it has been found entirely impracticable. But, nevertheless, where a planter has only a few acres of cotton and there is an abundance of cheap labor, such as that of children, the method has been found very effective.

FUTILE MEANS.

The very serious nature of the boll weevil problem is constantly illustrated by the manner in which various useless devices and nostrums are brought to public attention. At one time it was widely spread about that mineral paint would act as a specific against the weevil. An equally fallacious theory that also received considerable popular attention was to the effect that cotton-seed meal exerted a powerful attraction for the pest.

Probably the most important useless recommendation has been that of spraying. It was supposed for some time by certain parties that it might be possible to poison weevils economically by attracting them to some sweetened preparation. The experiments detailed on pages 52 to 56 of this bulletin regarding the attraction of various sweetened substances demonstrate the fallacy of the theory. Even if these substances exerted as much attraction as was supposed, there would be insurmountable difficulties in the application of the method in the field. Spraying of a field crop has never been a success and, unless entirely new methods are eventually perfected, never will be of any practical importance. It is true that it is possible to destroy a certain number of weevils in regions where seppa cotton occurs by heavily spraying the earliest plants, but this method is of immeasurably less importance than the simple practice of cultural methods.

Many attempts have been made to perfect a machine that will assist in the warfare against the weevil. They have been designed to poison the insects, to jar them and infested squares from the plant and to collect them, to pick the fallen squares from the ground, to kill by fumigation, and to burn all infested material on the ground. The Division of Entomology has carefully investigated the merits of representatives of all of these classes, beginning in 1895 with a square-collecting machine that had attracted considerable local attention in Bee County. Up to the present time none of these devices have been found to be practicable or to offer any definite hope of being eventually successful. At one time there was some hope that a machine designed to pick the squares from the ground by suction might be perfected. The experiments, however, have indicated probably insurmountable difficulties; and an implement concern, after having experimented with the matter fully and after having expended over $5,000, has come to the conclusion that mechanical difficulties will always prevent the perfection of such a machine. If it were not possible to raise cotton profitably without the use of a machine, the situation would be changed materially; but since it is possible to produce the staple without the use of any other means than those which enter into cotton culture everywhere, there seems no hope for these machines.

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