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FARMERS' BULLETIN

557

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
October 2, 1913.

THE POTATO-TUBER MOTH.[1]

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INTRODUCTORY.

For many years the potato-tuber moth, known scientifically as *Phthorimæa operculella* Zell., has been the worst potato pest in California. It has now reached the State of Washington and southern Texas and menaces adjacent States. This insect feeds also upon tomato, eggplant, and tobacco, which do not, however, as a rule, suffer much injury. When it occurs on tobacco it is known as the splitworm.

The mature moth of this species, which is quite small and grayish in color, is shown in figure 1, *a;* the larva is shown in *b* and *c;* and the pupa in *d*. Sizes are indicated by the size lines in the figure.

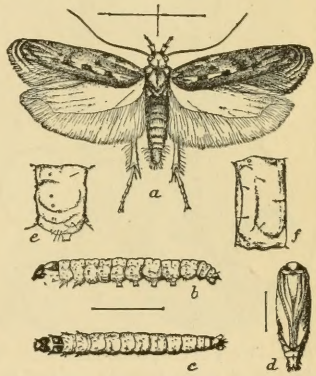

Fig. 1.—The potato-tuber moth (*Phthorimæa operculella*): *a*, Moth; *b*, larva, lateral view; *c*, larva, dorsal view; *d*, pupa; *e*, *f*, segments of larva, enlarged. (Redrawn from Riley and Howard.)

The eggs may be laid upon the leaves or on other parts of the plants, and the minute caterpillars or worms quickly bore between the surfaces of the leaves or into the potato skin, which they mine in every direction, finally devouring the exterior. It is believed that there are two or more generations in the course of a summer, and certainly another one can be produced in store. It thus happens that this insect belongs to both truck-crop and stored-product insect pests.

An example of injury by this species to potatoes is shown in figure 2. At *a* is a section showing the eggs; at the left is a section of a badly infested potato containing two pits, *d* and *f*, in which the larva has been at work, while at *b* and *c* is shown the egg, highly magnified. Figure 3 gives an exterior view of a potato which has been destroyed by the tuber moth.

[1] The account here given is issued with the purpose of warning potato growers and giving general information in regard to remedies. Work was begun on this species in 1912 and will continue. This is a revised and amplified account, first published as Circular 162 of the Bureau of Entomology.

DISTRIBUTION.

This species is widespread in its distribution, but in this country, until the year 1912, we did not know of its rapid dissemination. Abroad it is well known in Hawaii, all portions of Australia, New Zealand, Algeria, the West Indies, Peru, and many other countries, including southern Europe. As an enemy to tobacco it has been known for several years in Florida, and in North Carolina, South Carolina, and Virginia.

The species occurs in southern California practically wherever potatoes are grown commercially, extending its range northward to the Sacramento Valley.

As an enemy to eggplant and ground cherry it has been observed as far north as the District of Columbia.

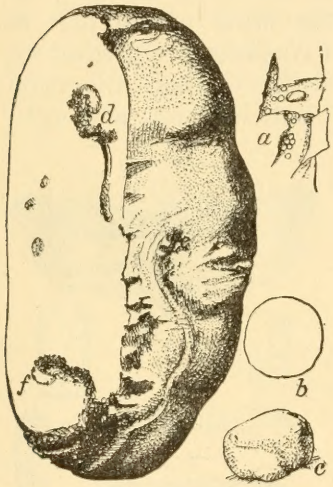

FIG. 2.—Work of the potato-tuber moth: *a*, Section of tuber, showing eye and eggs deposited about it; *b*, egg in outline; *c*, egg, lateral view; *d*, *f*, mines of larva in potato. *a*, Natural size; *b*, *c*, greatly enlarged; *d*, somewhat reduced. (Redrawn from Riley and Howard.)

The directions for applying remedies which follow are for the benefit of persons inquiring in regard to means of control. Which of these should be used can be best determined by trial in the different localities under the different conditions in which the insect exists. This applies especially to the question as to the best material for fumigation.

EVIDENCE OF IMPORTANCE.

As evidence of the importance of the pest Mr. J. E. Graf, working under the direction of the writer, wrote:

> In September, 1912, an unusual outbreak of this pest occurred at El Monte, Cal., due entirely to a combination of circumstances. Thousands of acres of potatoes were planted in southern California—many more than the market would stand. This meant that the market was continually clogged and the prices were poor, so that the crop was worked off very slowly. The tuber moth (*Phthorimæa operculella*) is always found here, but the crop is generally handled so quickly and carefully that small loss results. This year, however, careless work and the leaving of potatoes in the ground too long have given the insect a tremendous start, and now its ravages are greater than ever before. A combination of the moth and low prices has so discouraged many of the growers that they are leaving their potatoes to rot, and as these are becoming infested there will be a great number of moths waiting for the fall potatoes. * * *

Later, September 17, 1912, Mr. Graf wrote in regard to injury by this species that two growers near El Monte, Cal., lost $90,000 and $70,000, respectively, on potatoes that year. Items of this kind show the necessity of investigating the problem.

Aside from numerous similar complaints, including the usual number from California for the past two years, this species has been received from Eagle Lake and Hallettsville, Tex.; San Jose, Costa Rica; Seattle, Auburn, and Yakima, Wash.; New York City, where it has not become acclimatized so far as known; Fort Collins, Colo.; and Larimore, N. Dak. These records include only occurrences on potato.

In the case of the last report the tuber moth was stated to have been imported into southern California in potatoes from China. It is doubtful if the species has been established in North Dakota, but inquiries have been made in regard to the danger of its being introduced there as well as into Minnesota and many other States.

FIG. 3.—Work of the potato-tuber moth. Exterior view of potato. (Original.)

REMEDIES.

The potato-tuber moth is a difficult insect to control by any single method. It is not possible to reach the tuber worms in their mines in the potatoes or in the stalks or tubers while growing in the field, which makes it necessary to proceed against the pest by other methods. Of these, several must be employed to insure success.

CLEAN METHODS OF CULTIVATION.

The first measure consists in the maintenance of clean methods of cultivation. This implies that all infested potato plants and solanaceous weeds, such as ground cherry, bull nettles, horse nettles, and volunteer potato plants, growing in the same vicinity as the potatoes, must be destroyed. This can be done by prompt burning as soon as insect infestation is manifest. The burning of these weeds will eliminate places for the breeding of the insect or for its successful hibernation. Domestic animals, such as sheep and hogs, are valuable for the destruction of remnants and may be utilized by merely turning them into the field.

CROP ROTATION.

As in most other cases of insect injury, crop rotation is desirable where possible, and the cooperation of all potato growers of the neighborhood is practically a necessity. In certain cases, as, for ex-

ample, in a county where many potatoes are grown, it might be possible by legislation to enforce the discontinuance of potato planting for a year, requiring at the same time the destruction of the weeds which serve as food plants. There are several alternate food crops which do not suffer materially from this insect. About the best of these are leguminous crops, like beans, peas, cowpeas, alfalfa, and clover. These possess a dual value, as they all act as soil restorers. Sugar beets, celery, and crucifers are also good as alternate food crops. Grains may serve in the same way, as they are not attacked by the tuber moth.

Care in digging is advisable in order not to cut into the tuber or leave the dug potatoes in the field over night where reinfestation could occur.

FUMIGATION.

While all of these remedies are of value, the best remedy is the fumigation of infested tubers with bisulphid of carbon or hydrocyanic-acid gas. If bisulphid of carbon is used, it should be at the rate of 3 pounds to 1,000 cubic feet of air space, including the potatoes; 1 ounce to a barrel of 96 pounds' capacity would not be excessive. With an exposure of not more than 24 hours no harm should be done to the potatoes for planting. The bisulphid should be evaporated in tins, like pie plates or pie pans, and a cover should be placed on the top of the fumigating barrel or box so as to make it as nearly air-tight as possible. At the end of 24 hours the potatoes should be removed, placed in a fresh barrel, and closed up.

Where it can be conveniently done, hydrocyanic-acid gas should be used in a specially constructed fumigator (see fig. 4), also gas-tight. *In the case of bisulphid of carbon there is great danger in bringing the chemical into proximity to fire, such as a lighted lantern or cigar, for the gas is highly inflammable and even explosive.* Then, too, the bisulphid-of-carbon method costs slightly more than the hydrocyanic-acid-gas method.

Fumigation with hydrocyanic-acid gas, properly performed, is not dangerous, but if improperly performed it is decidedly dangerous to human and other animal life, as the fumes are very poisonous and are *deadly* when inhaled in any amount. This gas is more penetrating than bisulphid of carbon and can be used by an intelligent person without trouble, if he first familiarizes himself thoroughly with the procedure by carefully studying the printed directions or assisting some one who has had experience in this work. The cubic contents of the receptacle to be fumigated, on which is based the amount of chemicals to be used, can be readily computed.

The fumigating box shown in the illustration, which will presently be described, may merely be taken as an example of what can

be easily constructed to meet the purpose. In the case of this box the potatoes are best fumigated in bags, which can be piled one on top of another. If bins or other fumigators are used, the proportions will vary. They can be constructed longer or shorter and lower, according to the individual needs and desires of the potato grower.

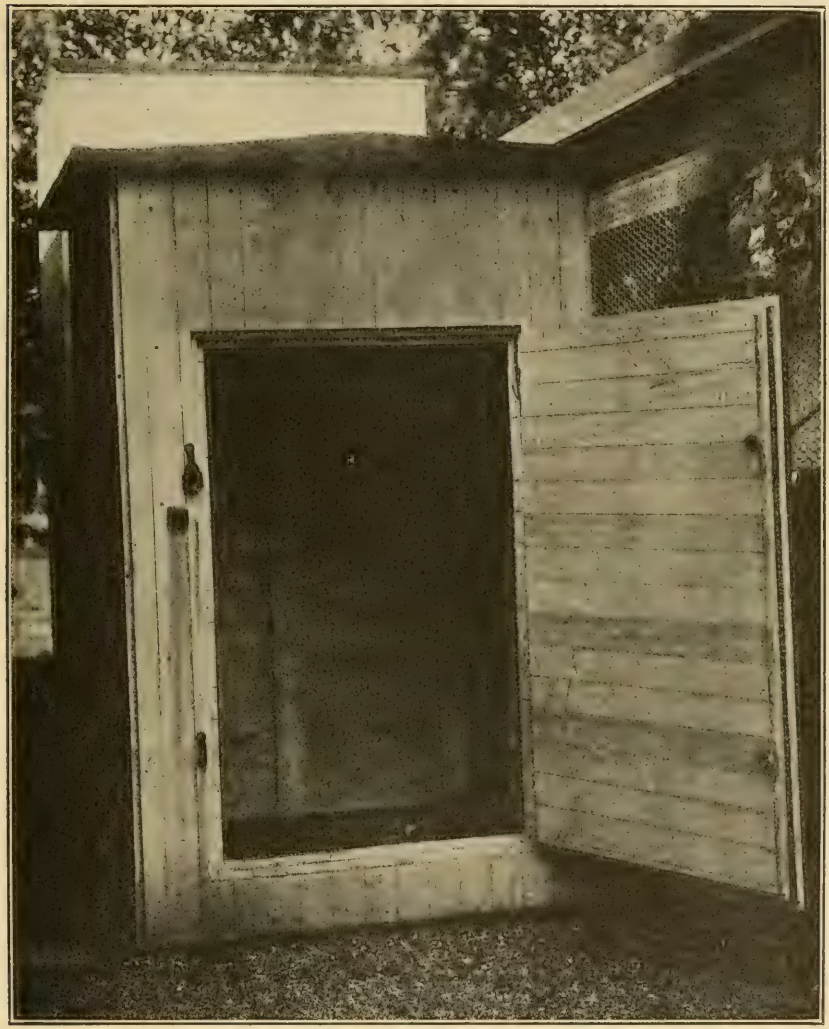

FIG. 4.—Fumigator used for stored products infested by insects. (Author's illustration.)

THE CONSTRUCTION OF A FUMIGATOR.

A building, box, or room (see fig. 4) of about 100 to 200 bushels capacity suitable for the fumigation of a quantity of potatoes would contain about 500 cubic feet. A fumigator of this cubic capacity might be built 8 feet square by 8 feet in height. A good, and perhaps

the best, means of preventing the escape of the gas is to line the fumigator with sheet tin, with soldered joints, and over sheathing. Another method is to sheath the room inside, cover the walls, ceiling, and floor with tarred or heavy building paper, with joints well lapped, and cover the inside with matched ceiling boards. The fumigator should always be equipped with a tight door in which the joints have been broken, similar to the door of a refrigerator or safe, and should close with two refrigerator catches against a thick felt weather strip, which should render it practically gas-tight. Thus constructed it would furnish sufficient space for the fumigation of about 200 bushels of material. There would also be sufficient space for the application and diffusion of the carbon bisulphid, hydrocyanic-acid gas, or other fumigant from the top with a charge more than necessary for the quantity of potatoes treated.

It sometimes happens that the price of potatoes is so low that the small grower can not well afford to expend the amount of money which would be necessary for the construction of a special fumigator. In such a case it would be advisable to use a barrel, preferably a large oil barrel, with a tight-fitting cover for fumigating. It is possible also to fumigate, but not thoroughly, piles of tubers by covering them as tightly as possible with canvas, such as 10-ounce duck or tarpaulin.

PROTECTION OF THE FALL CROP AND SEED POTATOES.

A special letter of warning against the ravages of the potato-tuber moth in the shape of a press notice has been sent broadcast to newspapers, as well as to others, throughout the country. The main facts in the case were founded on the experience of Mr. Graf in his investigations and in his dealings with the potato growers of southern California. Concisely stated, the warning is to enable potato growers to undertake special work with seed potatoes and with the fall crop.

For the protection of potatoes in fall against this pest it is urged that potato growers sort the potatoes for seed two weeks after digging and again two weeks later. The uninfested tubers should then be placed in a moth-proof bin. The infested tubers may be readily picked out because of the excrement of the larvæ which adheres by webbing to the outer skin of the potatoes. The tubers in the moth-proof bin, after final sorting, should be fumigated with carbon bisulphid (bisulphid of carbon) to destroy any moths which might have bred out or have obtained entrance through other means. Growers should now keep a careful lookout both in the field and among the fumigated tubers. At first those which have been fumigated should be inspected daily. Afterwards observations may be made every other day until finally once a week will suffice. If there should be any indication that the tuber moth is propagating, a second fumigation is in order.

This method of saving seed potatoes appears so simple, although effective, that it is feared that many growers may disregard it.

To grow all potatoes successfully the farmer should work overtime on a cleaning-up campaign which should begin at once on receipt of this bulletin. Small or useless tubers and tops should be promptly cleaned up and burned, and the land should be harrowed to break up clods and leave as few hiding places as possible for the moths. All weeds and other plants of the potato kind should be destroyed over large areas surrounding the potato fields.

It is particularly urged that potato growers cooperate in this work, which will lessen very materially the numbers of moths and hence reduce the chances for propagation. Could general cooperation be secured by legislation or otherwise it would be possible to restrict the distribution of this species to the area which it now occupies or to stamp it out where now established. Slipshod methods of raising potatoes at such a time as midsummer or early autumn are particularly dangerous, and in infested districts it is advisable in many cases to raise some crop other than potatoes, because unless protective and defensive measures are adopted at once there will be a serious reduction of the potato crop and similar trouble will be experienced during seasons to come.

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U.S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.
January 29, 1914.

THE GIPSY MOTH AND THE BROWN-TAIL MOTH, WITH SUGGESTIONS FOR THEIR CONTROL.

By A. F. Burgess,
In Charge of Gipsy Moth and Brown-tail Moth Investigations.

INTRODUCTION.

In 1869 a number of egg clusters of the gipsy moth (*Porthetria dispar* L.), a destructive insect pest in Europe, were brought from France to Medford, Mass., by a naturalist who was carrying on experimental work with insects. Later in the season some of the caterpillars escaped, and although none was found in the vicinity during the next few years, enough specimens survived to enable the species to establish itself. In the summer of 1889 this insect became so abundant that fruit and shade trees in the neighborhood were completely defoliated, and the caterpillars swarmed over the trees and into the houses and became a serious nuisance. This resulted in the loss of valuable trees and in the depreciation of property values in that section.

For about 10 years effective work against the gipsy moth was carried on by the State of Massachusetts, and during this period the insect was kept under control. The work was discontinued in 1900, but the species had become so abundant and had caused such widespread injury by 1905 that systematic work was renewed by the State in order to protect the tree growth in the infested area. This work has been continued up to the present time, and as the insect has spread to other New England States it has become necessary to institute more extensive control measures.

In 1906, after the gipsy moth had become established in New Hampshire and Rhode Island, as well as in Massachusetts, an appropriation was made by Congress for suppressing it, and the Secretary of Agriculture was authorized to take all possible measures to prevent its spread. Since that time work has been carried on each year. The area now known to be infested is shown on the accompanying map (fig. 1).

The brown-tail moth (*Euproctis chrysorrhœa* L.) was first found in the United States in Somerville, Mass., during the summer of 1897

and was undoubtedly introduced some seasons previous to that time on imported nursery stock. The work of preventing damage by this insect was undertaken by the State of Massachusetts soon after the pest was discovered. This species occurs in many sections of Europe and is often seriously injurious. It spreads rapidly because the females are able to fly long distances. The accompanying map (fig. 1) shows the area in New England which is now infested by the

FIG. 1.—Map showing area infested and quarantined for the gipsy moth and the brown-tail moth, 1913. (Original.)

brown-tail moth. Suppressive measures by the New England States and by the Federal Government have been directed against this insect as well as against the gipsy moth.

It is the purpose of this bulletin to give a brief statement of the life history and habits of these two species and to suggest the best methods that can be adopted for their control.

The methods of protecting orchards and the street, park, and ornamental trees in cities and towns are set forth on the following pages, and these methods have been adopted as a result of many extensive experiments. A proper system of orchard management can be adopted which will enable the owner of infested trees to protect them fully without very much expense additional to that required for the control of the other injurious orchard insects. The expense of caring for infested city or park trees is somewhat greater than in the case of infested orchards, but practical methods can be adopted which will not render the cost prohibitive.

The control of these insects in forests is extremely difficult, owing to the small amount of money that any owner can afford to expend in preventing injury to his woodlands. This being so it is usually more satisfactory to have the woodland examined by an expert familiar with the insects and the best measures to be used for their control in order that suggestions for treatment may be made which will be applicable to the conditions in each particular case. Such information can usually be obtained from the State or local officials engaged in gipsy moth and brown-tail moth work, and so far as possible this office will cooperate with owners and give practical advice and suggestions as to the management of their infested premises.

THE GIPSY MOTH.

LIFE HISTORY.

(Fig. 2.)

The eggs.—The female gipsy moth deposits a cluster containing 400 eggs or more, which she covers with buff-colored hair. Most of the egg clusters are laid during the month of July and hatch about the time the leaves begin to appear the following spring. They are deposited on the underside of branches of trees, on tree trunks, under loose bark, or in cavities in the trunks or branches, and are sometimes placed on stones or rubbish and in a variety of situations where they are concealed from view. As the female moth does not fly, egg clusters are seldom found far from the food plant upon which the caterpillars developed.

The larvæ.—The newly-hatched larvæ feed on the opening leaves, making small perforations. They grow rapidly and become full fed early in July. During this period they molt five or six times, and as they increase in size a larger proportion of the foliage is eaten, so that if the infestation is severe, trees may be completely stripped of foliage before the end of June.

The pupæ.—When full grown the caterpillars shed their skin and transform to pupæ, which are chestnut brown in color and provided with tufts of yellow hairs. They remain in this dormant stage for about 10 days, after which the adult insects emerge.

The adults.—The male moth is dark brown in color, with black wing markings, and flies well. The female is white, with black mark-

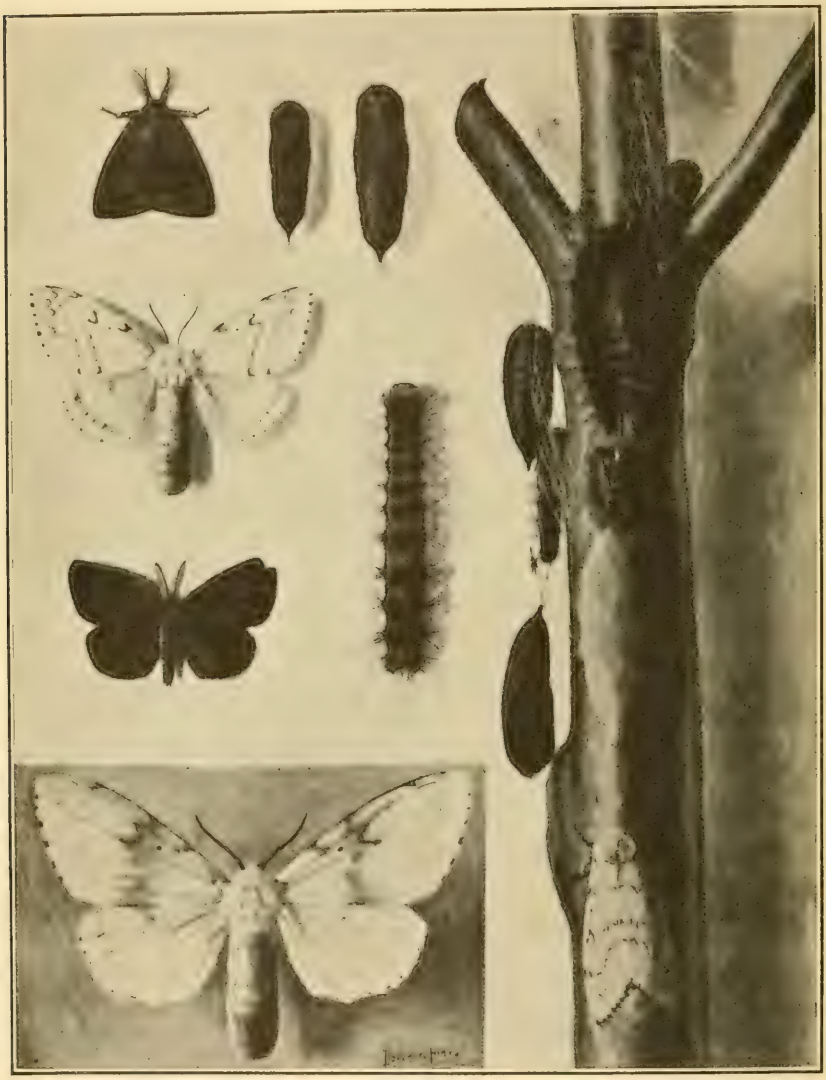

FIG. 2.—Different stages of the gipsy moth (*Porthetria dispar*): Egg mass on center of twig; female moth ovipositing just below; female moth below, at left, enlarged; male moth, somewhat reduced, immediately above; female moth immediately above, somewhat reduced; male moth with wings folded in upper left; male chrysalis at right of this; female chrysalis again at right; larva at center. (Original.)

ings on the wings, and does not fly on account of the weight of the abdomen. After mating the females begin depositing eggs.

FOOD PLANTS.

The most favored food plants of the gipsy moth are the apple, the different species of oak, gray birch, alder, and willow. In cases of bad infestation nearly all of our deciduous trees are injured to a greater or less extent, with the exception of ash. Hickory is not a favored food plant, although the foliage occasionally shows severe feeding. Chestnut will not support the gipsy moth when the caterpillars are in the first stage, and pine will not support the first two stages; but if other food plants are present severe injury may result from feeding by the larger caterpillars. Beech is sometimes fed upon freely, and occasionally the trees are defoliated; and the same is true of poplar.

INJURY CAUSED BY THE GIPSY MOTH.

Unless reduced in numbers by natural enemies, or by the application of control measures, the gipsy moth is capable of causing enormous injury to tree growth. In the area in New England which has suffered most from this insect thousands of trees are dead as a result of defoliation. (See fig. 3.) Apple and oak have been injured most, but pine and other coniferous trees mixed with deciduous growth have suffered severely.

It is undoubtedly true that many oak trees which have been severely weakened as a result of defoliation by the gipsy moth and the brown-tail moth have failed to recover because of the attacks of certain wood-boring insects. The species which has caused the most damage in this way is *Agrilus bilineatus* Web., a beetle the larva of which feeds beneath the bark of injured trees.

NATURAL ENEMIES.

There are few insect enemies of the gipsy moth native to New England that cause any noticeable benefit in reducing its numbers. This is shown by the fact that between the years 1900 and 1905, when no systematic effort was made to suppress the insect, alarming injury resulted, and native insect enemies did not increase to any marked degree. The same is true of the work of native insectivorous birds. While they undoubtedly feed to some extent on gipsy-moth caterpillars, there is no case on record where they have been able to control the species. The wilt disease, which possibly may have occurred in this country for many years, has only recently become sufficiently abundant to be a prominent factor in natural control.

INTRODUCED PARASITES AND ENEMIES.

In 1905 an effort was made by the State of Massachusetts, in cooperation with the Bureau of Entomology, United States Department of Agriculture, to introduce the parasites and natural enemies of the

gipsy moth from its native home in Europe and Japan. Since that time a large amount of parasitized material has been received nearly every year, and as a result some promising natural enemies have become established in this country and are assisting in bringing about the control of the species. The enemies which have become estab-

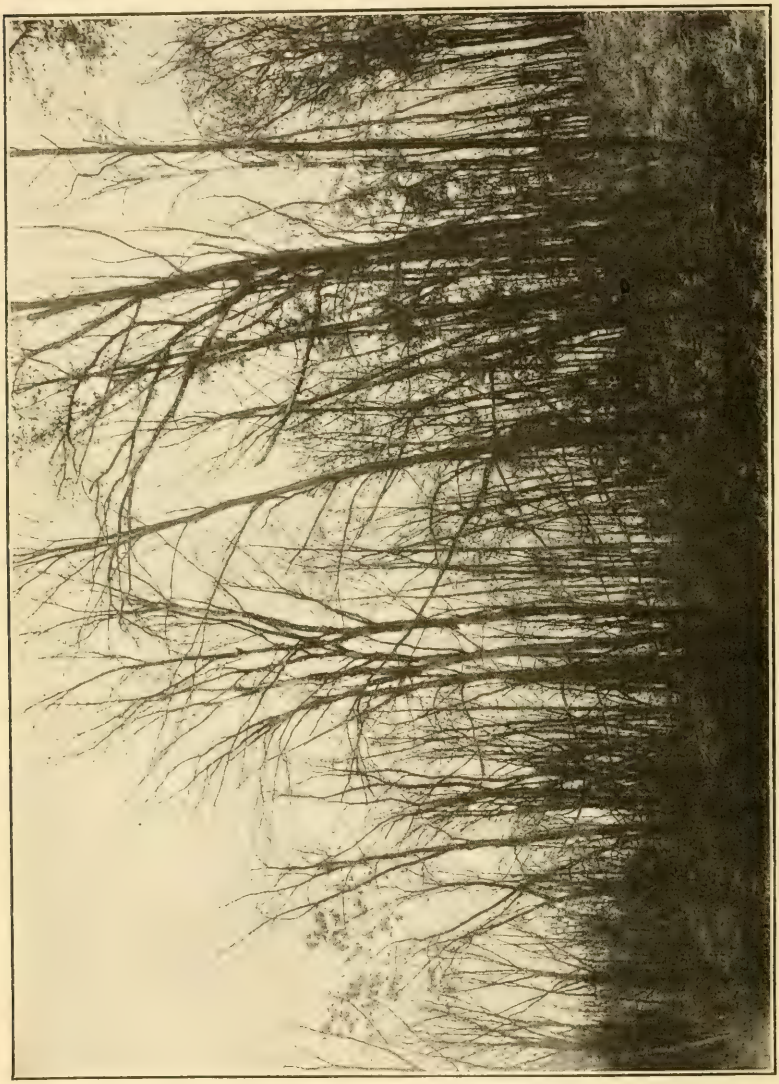

FIG. 3.—Dead and defoliated woodland resulting from gipsy moth attack. (Original.)

lished and are at present destroying the largest number of gipsy-moth caterpillars and pupæ are a Calosoma beetle (*Calosoma sycophanta* L.); a tachinid fly (*Compsilura concinnata* Meig.), which is also a parasite of the brown-tail moth; and a species of Apanteles (*Apanteles lacteicolor* Vier.), which attacks small gipsy-moth and small

brown-tail moth caterpillars. Two species of egg parasites, namely, *Schedius kuvanæ* How., which was imported from Japan, and *Anastatus bifasciatus* Fonsc., which was secured from Europe, have also been colonized in a portion of the infested area and are valuable additions to the natural enemies of this insect.

During the past year the work of the natural enemies of the gipsy moth, including the imported parasites, the Calosoma beetle, and the wilt disease, has served greatly to reduce the numbers of the insect in many badly infested localities. This is particularly true in the region which has been infested longest, and it is hoped that when these enemies of the moth have become established in large numbers over the entire infested territory the insect will be much less a destructive factor than it is at present. Until such time as this can be brought about, however, the most effective hand or mechanical methods of fighting this pest should be continued.

THE BROWN-TAIL MOTH.

LIFE HISTORY.

(Fig. 4).

The eggs.—The female brown-tail moth deposits a small cluster of eggs on the underside of a leaf. These eggs are usually laid in July and are covered with brown hair taken from the body of the female. Hatching begins about the 15th of August.

The larvæ.—The newly hatched larvæ of this insect feed on the epidermis of the leaf and after molting once or twice begin to construct a winter web. This is made by drawing together several terminal leaves and securely fastening them by silk which is secreted by the caterpillars. The larvæ from one or more egg clusters live and feed in common, and as cold weather approaches they retire to the web, in which they remain during the winter. In the spring these larvæ leave the web as soon as the buds begin to develop and feed upon the bud scales and small leaflets. They become full-grown about the middle of June.

The pupæ.—After the caterpillars finish feeding they spin loose silken cocoons and pupate within them. These cocoons are sometimes constructed separately, but in many cases large numbers of them are spun in a single mass. About two weeks are spent in the pupal state.

The adults.—Emergence of the moth usually begins the first week in July. The adult brown-tail moth is pure white in color. The abdomen of the female is much larger than that of the male, but in both sexes the tip of the abdomen is covered with dark-brown hairs. These moths are attracted to strong light, such as electric arc lights, and as they fly at night it is often possible to secure many specimens around the arc lights in cities and towns during the first half of the month of July.

FOOD PLANTS.

The caterpillars of the brown-tail moth commonly feed on apple, pear, plum, oak, and willow, and they are sometimes found in con-

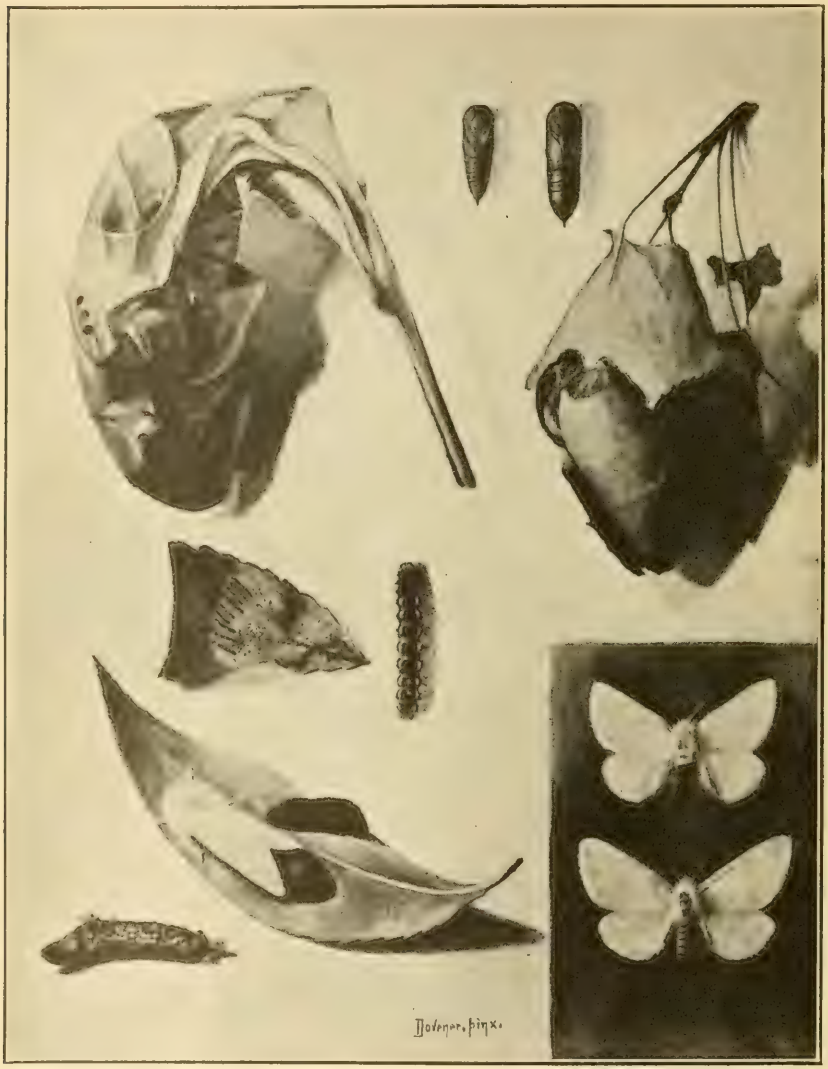

FIG. 4.—Different stages of the brown-tail moth (*Euproctis chrysorrhœa*): Winter nest at upper left; male and female adults, lower right; cocoon in leaves, upper right; male and female chrysalides above, male at left; full-grown larva in center, somewhat reduced; young larvæ at its left; egg mass removed from leaf, showing single eggs, at lower left; female ovipositing on leaf; egg mass also on same leaf. (Original.)

siderable numbers on elm, maple, and rose and in smaller numbers on other common deciduous trees and shrubs. They never attack conifers and are seldom found on hickory, ash, chestnut, or birch.

INJURY CAUSED BY THE BROWN-TAIL MOTH.

The principal injury caused by the brown-tail moth is due to the feeding habits of the larvæ in the spring. If the infestation is bad the caterpillars are often numerous enough to devour the leaves as fast as the trees are able to develop them. As the webs are made on the terminals, the growth of the trees is often severely checked. In

FIG. 5.—Apple trees stripped by brown-tail moth caterpillars. Note old winter webs at tops of trees. (Original.)

severe infestations trees may be completely stripped (figs. 5, 6), but as the larvæ become full-grown during the first part of June, there is usually an opportunity for the trees to refoliate before midsummer. The young larvæ that hatch in August frequently skeletonize the leaves to a considerable extent. This does not damage the trees seriously, as the growing period for the season is nearly completed.

The bodies of the caterpillars of the brown-tail moth are provided with poisonous hairs. A microscopic examination of these hairs shows that the edges are barbed in such a way that when they come

FIG. 6.—Red oak trees stripped by brown-tail moth caterpillers. Note old winter webs at tops of trees. (Original.)

in contact with the human skin and are pressed into the flesh, intense irritation is caused. These hairs are also hollow and contain a poisonous substance which acts on the blood corpuscles. This causes

serious poisoning and severe irritation accompanied with external swelling and is known as the brown-tail rash. There is considerable difference in the susceptibility of persons to this poison, but many cases are reported each year in the infested region, most of which are more serious than those of ivy poisoning. Many camps and summer cottages, particularly in wooded areas, can not be occupied with any comfort during the early summer on account of the poisoning resulting from these caterpillars. If clothing is hung on the line near badly infested trees the hairs frequently find lodgment and are brought into the houses, and later severe poisoning may result.

NATURAL ENEMIES.

One of the most important natural enemies of the brown-tail moth is a fungous disease, *Entomophthora aulicæ*, which attacks the caterpillars, particularly in the spring. It was first reported in this country by Dr. Roland Thaxter in 1888. Like all diseases of this nature, the benefit derived from it is regulated largely by favorable or unfavorable weather conditions. This fungus sometimes works to a slight degree on the small caterpillars in the fall, and in some instances it is found in the winter webs. As a rule, however, the greatest mortality of caterpillars takes place in the spring, when they are nearly full-grown, and the pupæ of the moth may, under the most favorable conditions, be almost completely exterminated. Native parasites and predaceous insects have done very little to check the increase of the brown-tail moth.

INTRODUCED PARASITES AND ENEMIES.

The parasites and enemies already mentioned as being particularly valuable for their work in destroying the gipsy moth also attack the brown-tail moth, with the exception of the egg parasites. The Calosoma beetle, *Calosoma sycophanta*, and its larvæ do valuable work each year in destroying brown-tail caterpillars and pupæ, and the dipterous and hymenopterous parasites also attack this species in considerable numbers. Another imported parasite, namely, *Meteorus versicolor* Wesm., has become established in this country and is doing good work. It attacks the brown-tail moth caterpillars, but not those of the gipsy moth.

In some parts of the infested territory where some of the first parasite liberations were made a marked decrease in the number of moths has been noted during the past two years. The work of the parasites will undoubtedly be more pronounced after they have become more abundant over the entire infested territory.

HAND METHODS FOR CONTROLLING THE BROWN-TAIL MOTH.

The brown-tail moth can be controlled by cutting off the winter webs and burning them before the caterpillars begin to emerge in April. These webs should be destroyed by fire, for if they are simply cut from the tree and left on the ground the caterpillars will emerge and no benefit will result from the work which has been done.

In orchard practice it is sometimes inadvisable to cut the winter webs, for where an infestation is bad it is likely to leave a poorly shaped tree. Spraying in the spring is not a satisfactory remedy unless the infestation is very light, because the caterpillars, when they occur in large numbers, do not allow the tree to put out sufficient foliage to hold the spray material. The most effective method is to spray the trees before the middle of August, using from 6 to 10 pounds of arsenate of lead to 100 gallons of water. Before spraying operations of this sort are attempted care should be taken to determine whether the trees are well infested with egg masses of the brown-tail moth, for if the infestation is very slight it will be more satisfactory to cut and destroy the webs. If the infestation warrants, both shade, ornamental, and fruit trees may be sprayed to advantage at this time. Caution should be used, however, in spraying fruit trees, particularly if early fall varieties are to be treated. If this is to be done a somewhat weaker spray solution may be used, provided it is applied as soon as the caterpillars begin to hatch. The foliage should be treated thoroughly, particularly the terminal shoots, and as much care as possible should be exercised not to cover the fruit. Late fall or winter varieties of fruit may be sprayed in August with arsenate of lead, using 6 pounds to 100 gallons of water, and although an occasional spot may be found on the fruit at the time of picking no injury will result from it. In cases where only a few choice fruit trees are to be sprayed it is practicable to wipe the fruit before packing for sale; but this is not necessary if care is taken to treat the terminal growth of the trees, as this is where the bulk of the egg clusters is deposited.

GENERAL HAND METHODS FOR CONTROLLING THE GIPSY MOTH.

Creosote.—One of the best methods of controlling the gipsy moth is to treat the egg clusters of the insect between August 1 and April 1 with creosote, to which a small amount of lampblack has been added. This mixture is applied with a brush, and it leaves a black residue on the clusters treated. Creosote may be obtained in small quantities from nearly all the large hardware or seed stores in the infested district, where it usually sells for about 35 cents a gallon. If secured in larger quantities a much lower price can be obtained.

Burlap bands.—Gipsy moth caterpillars usually seek shelter during hot, sunny days, and if a band of burlap is attached to a tree large numbers of them will crawl beneath it, where they may be crushed each day. Ordinarily a strip of burlap about 8 inches wide is placed

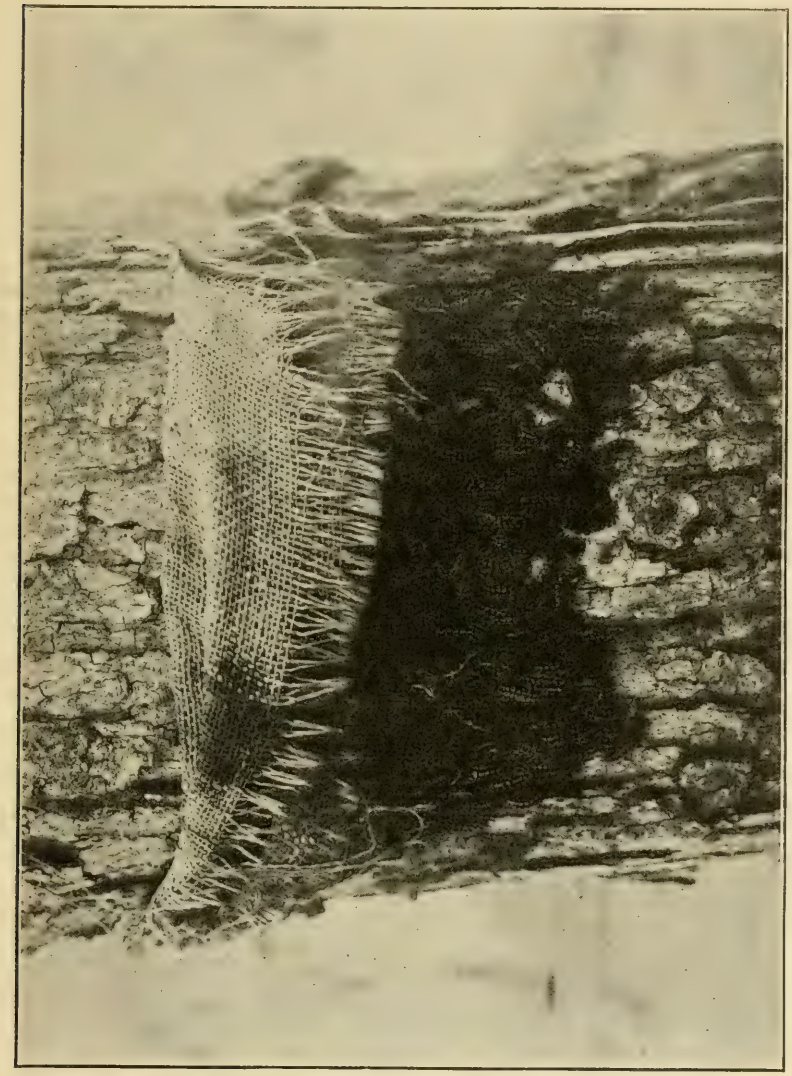

FIG. 7.—Burlap band on tree. The caterpillars beneath it are nearly all those of the brown-tail moth. (Original.)

loosely around a tree trunk and a piece of twine passed around the center and tied to hold it in place. After this is done the top part of the burlap is folded down so that a double shelter is made beneath it. The use of burlap bands has been discontinued to a great extent during the last few years, owing to the expense involved and because

of the fact that if the burlaps are applied early in the season, before the brown-tail caterpillars have pupated, an excellent place is fur-

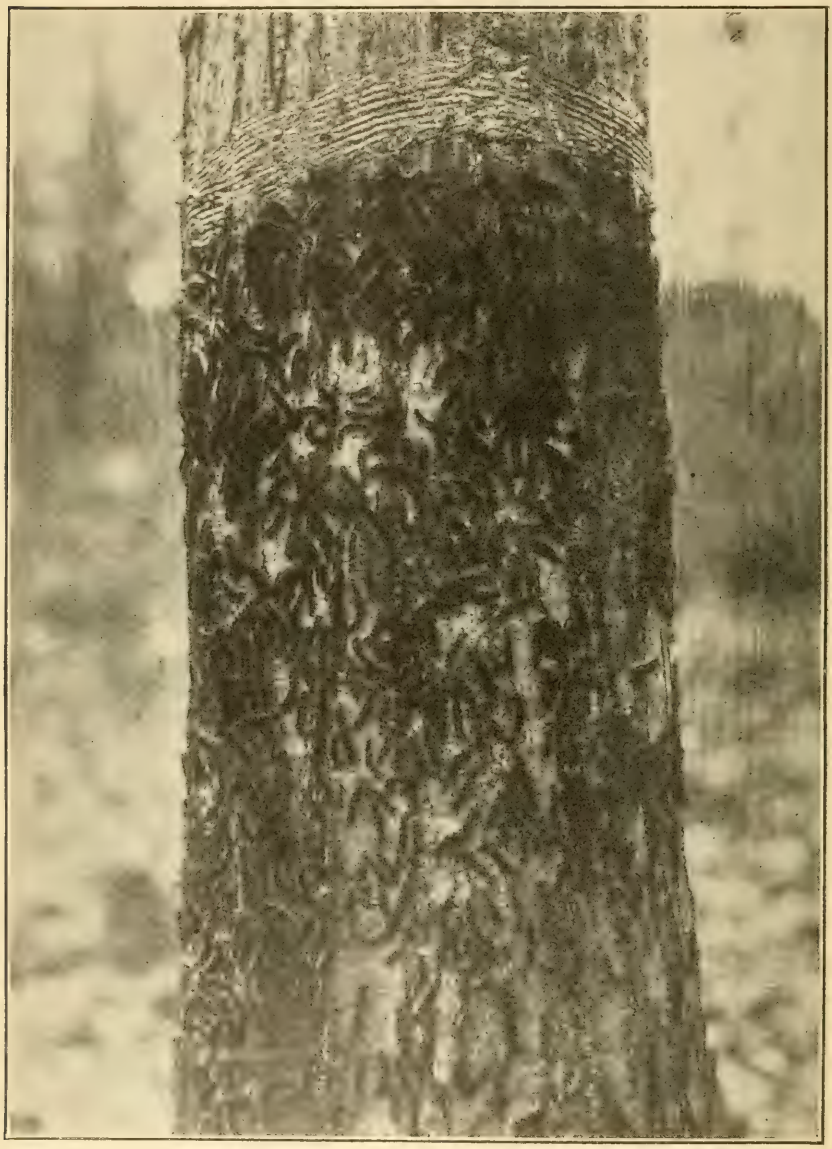

FIG. 8.—Tanglefoot band. Note that there are enormous numbers of gipsy moth caterpillars below the band and on the ground, but none above it. (Original.)

nished for these poisonous caterpillars to make their cocoons (see fig. 7), and severe poisoning results to the workmen. If this method

is to be used at all the burlap should not be attached to the trees until after June 15, when most of the brown-tail caterpillars will have pupated.

Tanglefoot bands.—A band of tanglefoot may be used on tree trunks after the bark has been scraped so that the sticky material can be applied evenly in a thin layer with a paddle. The purpose of this band is to prevent caterpillars from ascending the trees, and if the egg clusters have previously been treated this is a very effective measure. It is necessary every week or 10 days during the caterpillar season to run a comb or other similar implement around the band in order to prevent hardening of the surface and to bring up fresh, sticky material from the part of the band near the bark. (See fig. 8.) Placing these bands on the trees prevents the caterpillars from reaching the foliage; and as the latter usually mass in large numbers beneath the bands, conditions are favorable for wilt disease to develop, and the caterpillars often die in large numbers from this cause and from starvation.

Spraying.—The most effective spray for the gipsy moth is arsenate of lead paste applied to the foliage at the rate of 10 pounds to 100 gallons of water. It is necessary that the treatment be thorough and the application even, if best results are to be secured. For small operations the ordinary orchard sprayer may be used with one or more lines of hose equipped with nozzles of the Vermorel or Bordeaux type. In case large shade trees on valuable park or woodland are to be treated, however, the use of a high-power sprayer is more economical. The type that has given the most satisfactory results in the gipsy-moth work develops sufficient power to throw a solid stream of spray into the trees. The nozzle is constructed so that the stream will break into a fine mist high in the air, and this results in very satisfactory and rapid treatment. (See fig. 9.) With such a sprayer it is unnecessary to climb trees and use small lines of hose, which is a slow and expensive operation. A satisfactory high-power sprayer for this work should be equipped with a 10-horsepower gasoline engine and a triplex pump capable of delivering 35 gallons of liquid per minute at a pressure of from 200 to 250 pounds. This machinery, together with a 400-gallon tank, should be mounted on well-built trucks. One-inch hose is used, and with the outfit mentioned the spray material can be conducted through several hundred feet of this hose without seriously reducing the nozzle pressure, which should be maintained at about 230 pounds.

HAND METHODS TO BE USED AGAINST THE GIPSY MOTH IN ORCHARDS.

The methods to be used for controlling the gipsy moth in orchards should be based largely on the severity of the infestation. If only a

few egg clusters are present in the orchard, early spraying, such as is applied for the codling moth after the blossoms fall, will be found useful, providing the amount of poison used is increased to 10 pounds

FIG. 9.—High-power spraying outfit in use in treating roadside trees. (From Rogers and Burgess.)

to 100 gallons of water. If the infestation is more serious, a second spraying early in June, using a similar amount of poison, will be found very satisfactory. In cases where the infestation is severe it

will probably be necessary to creosote egg clusters in the winter and spray in the spring if the insect is to be controlled. In any case thoroughness is a prime essential if good results are to be secured.

All poor or hollow trees should be removed, and if badly infested woodland is near by the orchard trees should be banded with tanglefoot. Orchard infestations can be managed by following up these methods, and it will not require much additional expense or a great deal of extra work to protect the trees. In making this statement it is assumed that the orchard is being cared for by up-to-date methods in order to protect it from the codling moth and other injurious insects and diseases, and it is improbable that these results can be brought about in neglected orchards or where the owners do not practice the best horticultural methods in handling their growing trees.

HAND METHODS FOR CONTROLLING THE GIPSY MOTH IN CITIES AND TOWNS.

The same methods that are used in orchards are applicable in cities and towns and for the treatment of park and shade trees. In certain instances it would probably be advisable to use tanglefoot bands or burlap, preferably the former, and to discontinue spraying in cases where the infestation is light or moderate. If the infestation is bad, creosoting, tanglefooting, and spraying should all be used in their season, in order to bring the insect under control and reduce the numbers present to a minimum.

The proper method of handling the gipsy moth in any town, city, or park or on private estates, should be based on the infestation as determined by some one who is familiar with gipsy-moth work, if the best results are to be secured at a minimum expense. Much energy and money may be wasted in applying remedies unless their application is based on a thorough knowledge of existing conditions. An owner of an infested estate should have an examination made by some qualified person who can give reliable recommendations as to treatment. It should be borne in mind that conditions as to infestation vary from year to year, and this should be considered when plans for treatment are being made.

METHODS OF CONTROLLING THE GIPSY MOTH IN WOODLAND.

Satisfactory control of the gipsy moth in woodland by the employment of hand methods such as have already been mentioned is entirely impracticable unless the tree growth is particularly valued for purposes other than lumber. If the woodland is situated near a large city and occupies space that is likely to be utilized in a few years for building lots, considerable money may be expended to advantage in protecting the trees, as these will make the property much

more valuable when the land is subdivided. Limited areas of woodland on private estates may be of sufficient value to the owners to justify a considerable expenditure for moth destruction. In all cases, however, the species of trees involved should be carefully studied before a plan of work is adopted in order that the expense may be reduced as much as possible. Unfortunately the difficulty of treating the woodlands in the infested area of New England is considerably increased by the fact that they are for the most part composed of a variety of species in mixture.

Experiments have shown that coniferous trees are not injured by the gipsy moth if grown in isolated pure stands, and if the growth is such that the trees can be thinned to a stand of conifers no hand suppressive measures are necessary in order to prevent injury by this insect. (See fig. 10.) Such lots will also be immune from attack by the brown-tail moth, as the larvæ of this insect do not feed on conifers.

If mixtures containing a large percentage of deciduous trees are to be protected from moth injury it is very necessary that the species involved should be carefully considered before a decision is reached as to the best methods of treatment. Sometimes practical methods of thinning can be adopted so that species will be left that are only slightly subject to injury by these insects. A limited number of experiments have shown that mixtures of chestnut, pine, red maple, ash, and hickory, regardless of the proportion of each species, are seldom injured by the gipsy moth.

In woodlands the oaks are the most favored food plant of this insect, and unfortunately the infested region abounds in large areas where these species predominate. At present there seems to be no means aside from hand treatment which will prevent serious injury to oak woodland, but as a large part of such land consists of poor sprout growth the amount of damage sustained is not always so great as it might at first appear. The greatest injury likely to be caused in such areas where oaks and gray birch abound is the dying of small seedlings of pine or other valuable species which have been denuded by the caterpillars after the oaks and birches have been defoliated. This leaves the prospective woodland in a much worse condition than it was before the defoliation took place and reduces greatly the chance that the sprout growth will be replaced by any species of value that can withstand gipsy-moth attack. This problem is being given special study and consideration in the hope that some economical method may be devised for protecting and improving wood lots of this character at moderate expense. It is true that there are considerable areas of oak woodland where the trees, although not mature, could be utilized for small timber, railroad ties, or cordwood, and in cases of bad infestation such woodland should be promptly cut if the wood can be sold to advantage. On cheap

cut-over or infested lands in many sections of the territory planting of white pine might be carried on to advantage, but as this involves

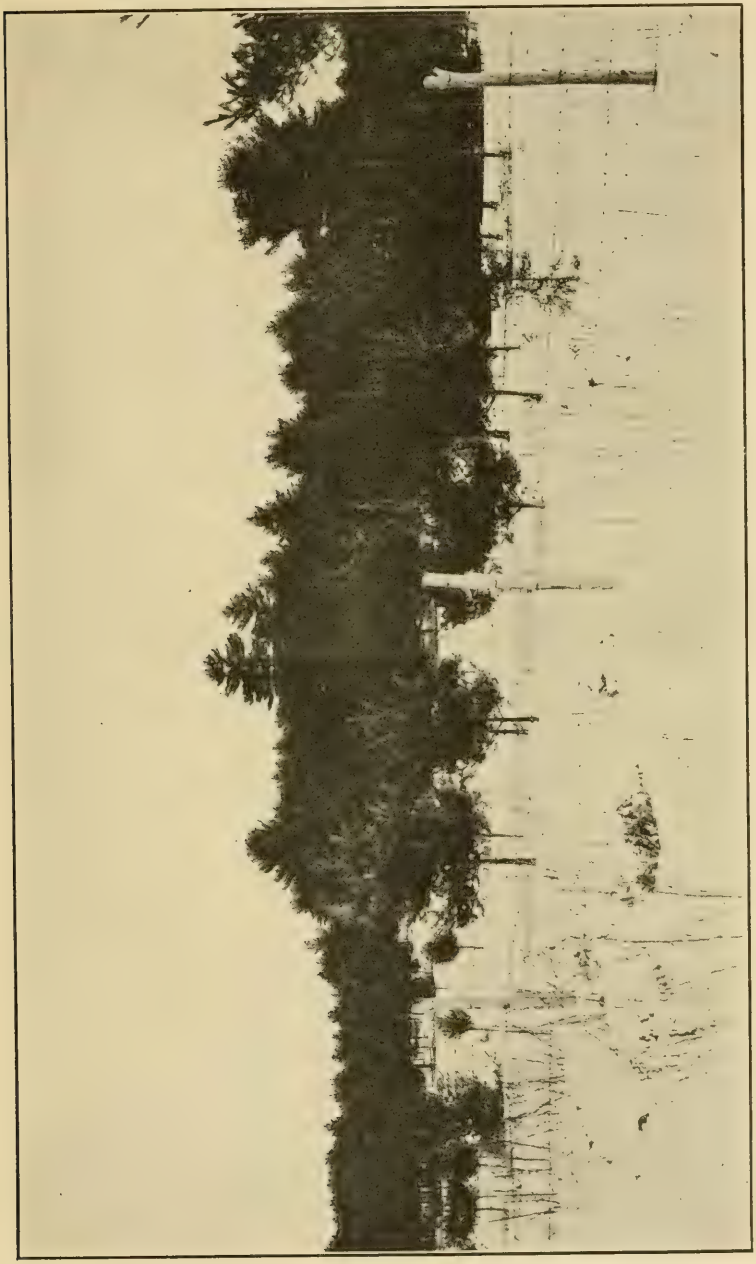

FIG. 10.—Solid white-pine block near Nashua, N. H.: Small trees in foreground were transplanted some years ago. The foliage of this species is not attacked by *small* gipsy-moth larvæ, so it is not injured if grown in clean stands. (Author's illustration.)

considerable expense and as the future crop can not be harvested for a period of years the question as to the desirability of managing

any wood lot in this way must in the end be decided by the owner of the property.

If the practice common in some European countries of maintaining municipal or state forests were well developed in the New England States it would be possible in a period of years to transform considerable areas of land which are now destined to be worthless, and which form a favorable feeding ground for the gipsy moth, into well-managed forests of valuable growth.

METHODS OF CONTROLLING THE BROWN-TAIL MOTH IN WOODLAND.

The damage caused by the brown-tail moth is ordinarily not so severe as is that resulting from gipsy-moth infestation because the former species does not have so wide a range of food plants and, further, because the bulk of the feeding is done early in the season so that the trees have an opportunity to recover before midsummer. In the territory where both insects exist the caterpillars of the gipsy moth supplement the work which is done by those of the brown-tail moth and the injury is therefore greatly increased. The large areas of oak-sprout growth furnish abundant food for brown-tail moth caterpillars, and as a result enormous numbers of the moths develop which migrate each season to the cities and towns and render it necessary for hand suppressive measures to be put in force each year. The area reinfested in this way depends largely on the prevailing winds during the month of July when the moths are flying. Elimination of oak, scrub apple, and wild-cherry trees would assist greatly in reducing the numbers of this pest.

STATE WORK AGAINST THE GIPSY MOTH AND THE BROWN-TAIL MOTH.

Each of the New England States is carrying on work for the control of these insects. The organization varies, as between the States, owing to differences in local conditions, but the same general methods of work are employed. A brief summary of the conditions of infestation in each State follows, with a statement of any special lines of work that are being attempted and the name and address of the State official in charge. Particular information concerning local conditions may be obtained by communicating with these officials.

Maine.—The work in Maine is in charge of the State commissioner of agriculture, who has authority to appoint a superintendent of moth work. The area badly infested by the gipsy moth is relatively small, but scattering infestations have been found throughout the southern part of the State. The entire area embraces about 4,850 square miles. Infestation by the brown-tail moth covers 12,450 square miles in the State. This species is a particularly serious pest

in the southern part of this territory and causes much injury and financial loss to the famous watering places along the coast. A moderate amount of work is being carried on each year by some of the towns in the infested area, but more should be done since under present conditions the residential sections can not be handled satisfactorily with the amount of funds available. State work is being carried on in the worst infested sections. The superintendent of moth work of Maine is Maj. E. E. Philbrook, Portland, Me.

New Hampshire.—Work in New Hampshire is in charge of a State agent appointed by the governor. Infestation by the gipsy moth throughout the southern part of the State is very heavy, and large areas of woodland have been completely defoliated during the past few years. The total area known to be infested by this insect is 4,960 square miles. The range of the brown-tail moth in New Hampshire is 8,100 square miles, and much loss has been caused during the past few years to the owners of woodland and summer property. Fortunately neither of these insects has become established in any great numbers in the White Mountain section of the State. Many of the towns in New Hampshire are cooperating with the State agent in an attempt to reduce the infestations, and progress in some sections is quite marked. The State agent is also carrying on a series of demonstration cuttings in wood lots in order to induce farmers and others to manage their woodland so as to prevent future moth injury. Prof. W. C. O'Kane, Durham, N. H., has charge of the work.

Vermont.—So far as is known, the gipsy moth does not occur in Vermont, but the brown-tail moth has become established in small numbers in several tiers of towns west of the Connecticut River. The work is in charge of the commissioner of agriculture, who has appointed a field deputy to look after the handling of infestations. The whole area known to be infested embraces about 2,635 square miles. Most of this infestation is recent, and owing to the thorough work done in the spring of 1913 it seems probable that the infested area will be reduced. Mr. E. S. Brigham, commissioner of agriculture, St. Albans, Vt., has charge of the work.

Massachusetts.—Moth work in Massachusetts is in charge of the State forester, but the law requires that each infested town shall appoint a local superintendent, subject to the approval of the State forester, who shall take charge of the work in his locality. The area infested by the gipsy moth in this State is 4,975 square miles. The brown-tail moth infestation covers 6,510 square miles. Each property owner is required by law to expend not to exceed $5 on each $1,000 valuation, and additional work is done in each town and paid for locally. The State appropriation is made in such a way that a certain amount of State funds can be used to assist towns which are most seriously infested or financially least able to bear the burden.

Aside from having general supervision over the entire work in Massachusetts, the State forester takes active charge of suppression work in certain sections of the State where money is subscribed by residents or interested parties for that purpose. Experimental and demonstration work is also being carried on by him with a view to so modifying the forest growth that it will be resistant to moth attack. Prof. F. W. Rane, 6 Beacon Street, Boston, Mass., is State forester.

Rhode Island.—Moth work in Rhode Island is in charge of the State board of agriculture and is placed by it under the supervision of the State entomologist. The gipsy moth infestation covers an area of 450 square miles. Brown-tail moth infestation covers the entire State—1,250 square miles. The gipsy moth infestation is not serious except in the region in and surrounding Providence, but infestation by the brown-tail moth has been worse than usual during the past year. The State entomologist is carrying on suppressive measures over as large an area as possible, but only a limited amount of local work is being done by the towns and cities to prevent injury by these insects. Prof. A. E. Stene, Kingston, R. I., is State entomologist.

Connecticut.—The moth work in Connecticut is in charge of the State entomologist. Only two gipsy moth infestations are known in the State and these have been practically exterminated. The brown-tail moth infestation covers a territory of about 1,475 square miles, and the area has increased considerably during the past year. Careful scouting has been done in all these towns and much thorough work by the State in order to reduce the infestation. At present no system of town or local moth work is in force in Connecticut. The State entomologist is Dr. W. E. Britton, New Haven, Conn.

New York.—A small colony of the gipsy moth was found in Geneva, N. Y., in 1912. Effective work has been done by the State department of agriculture, and the insect is now believed to be exterminated. A close watch will be kept on this locality for several years so that if any of the insects have been overlooked they can be promptly treated. Mr. George G. Atwood, chief horticultural inspector, Albany, N. Y., has charge of this work.

WORK CARRIED ON BY THE BUREAU OF ENTOMOLOGY.

The work carried on by the Bureau of Entomology of the United States Department of Agriculture is designed to prevent the spread of these insects. Owing to the freedom with which the female brown-tail moth flies it is difficult to prevent spread by hand suppressive means, as a heavy migration may take place into new territory during any year when the wind is favorable at the time the moths are flying. The spread of the gipsy moth has been much slower, but infestations are being found in territory along the line of the prevailing winds

when the gipsy moth caterpillars are hatching in the spring. It has been proved experimentally that the caterpillars, immediately after hatching, can be blown long distances, and of course such spread is very difficult of prevention. Fortunately the caterpillars must be active or they will not be caught up by the wind, and no activity is possible unless the temperature is high. From this it results that most of the wind spread is toward the north and northeast, so that the danger of spread by wind to territory outside of New England is not serious at present.

The work of the bureau is being carried on along several distinct lines, namely, experimental work, silvicultural investigations, quarantine work, and scouting work. The experimental work is conducted for the purpose of obtaining information which will serve as a basis for better control methods. It includes a thorough study of the food plants of the insects concerned and of the feeding habits of the caterpillars in their different stages, the rate of increase in the field, the means by which the insects are spread, the introduction and distribution of the foreign parasites and natural enemies of these species, and a study of the wilt disease, which has now become a prominent factor in reducing the infestation in many localities. The last investigation is being carried on cooperatively with the Bussey Institution of Harvard University, and Dr. W. M. Wheeler, who has charge of the economic entomology in that institution, is supervising the technical aspects of the work. A study is also being made, in cooperation with Dr. A. D. Hopkins, who has charge of the Forests Insect Investigations of this bureau, of the secondary insects which attack defoliated trees.

Silvicultural investigations are being carried on in cooperation with the United States Forest Service. Mr. G. E. Clement has been assigned from that service to this bureau for the purpose of conducting experiments to determine whether better silvicultural practices and improved methods of forest management can be employed as a help in checking the spread of these pests.

The entire infested area—15,235 square miles occupied by the gipsy moth and 32,420 square miles occupied by the brown-tail moth—has been placed under quarantine by the Federal Horticultural Board, and shipments of nursery stock, lumber, cordwood, and other forest products are not permitted to leave the territory unless they have been inspected and are accompanied by a certificate stating that they are free from infestation. This work is designed to prevent the spread of the insects for long distances and is being administered by Mr. D. M. Rogers.

The scouting work consists in making examinations in the towns outside the infested area and is directed by Mr. L. H. Worthley. This

work serves to establish the quarantine line. It is the policy of the bureau to carry on as much work as possible in the territory along the western border, for the purpose of stamping out new colonies that may become established and to prevent, so far as possible, further spread of the insect in this direction. A large number of men are employed on this work, and all the towns along the border were given attention this year from Lake Winnipesaukee on the north to Narragansett Bay. The work is carried on with special reference to the gipsy moth, as it would be impracticable to attempt control of the brown-tail moth in this way.

COOPERATIVE WORK.

Since work on the gipsy and brown-tail moths was begun by this bureau a greater or less amount of cooperative work has been carried on with the States concerned. As previously stated, the attempt to introduce parasites and natural enemies of the gipsy moth was conducted cooperatively with the State of Massachusetts for several years. Recently this entire line of work has been managed by the bureau, it being really a problem in which all the States concerned are vitally interested. During the past year Maine and New Hampshire have assisted in the work of collecting parasitized material and liberating it within their borders. The field work and the quarantine work is also carried on to a greater or less degree by means of cooperative arrangements with the States concerned, and since the work was first begun the relations with the various States have been very friendly and harmonious. Parasites have been liberated in greater or less numbers in all of the New England States.

THE OUTLOOK.

During the past season conditions in the oldest infested area have not been as serious as in previous years. The records show that the mortality of the gipsy moth and brown-tail moth caterpillars as a result of the attack of parasites, predaceous enemies, and disease has been greater than in any of the years preceding. The experiments which are being conducted are giving information which will serve as a basis for handling infestations more satisfactorily and economically, and although new territory has been found infested the outlook for diminishing the aggregate amount of damage which results from the work of these insects is more favorable than it has been heretofore. It is necessary, however, that aggressive measures should be continued in order that the pests may be brought under better control. This is of vital importance, particularly to the citizens of States where these insects do not now exist.

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U.S. DEPARTMENT OF AGRICULTURE
FARMERS' BULLETIN
595
Contribution from the Bureau of Entomology, L. O. Howard, Chief.
June 15, 1914.

ARSENATE OF LEAD AS AN INSECTICIDE AGAINST THE TOBACCO HORNWORMS IN THE DARK-TOBACCO DISTRICT.

By A. C. Morgan and D. C. Parman,
Entomological Assistants, Southern Field Crop Insect Investigations.

INTRODUCTORY.

In the dark-tobacco districts of Kentucky and Tennessee tobacco hornworms (*Phlegethontius quinquemaculata* Haw. and *P. sexta* Joh.) are the ever-present and most serious problem of the tobacco grower. Ten to twelve years ago, when labor was plentiful, cheap, and efficient, "hand worming" was found to be economical and effective in combating this pest. However, during the last six or eight years hand worming has become too costly, because of the great scarcity and inefficiency of labor, and the growers have been forced to employ an insecticide. At the time insecticides were first used Paris green was found to be the safest and most efficient. Nevertheless, there has always been complaint of frequent serious burning of tobacco as a result of its use. To find a safe and effective insecticide has been one of the main lines of investigation during the past five years. Arsenate of lead (diplumbic) has been found to meet the requirements.

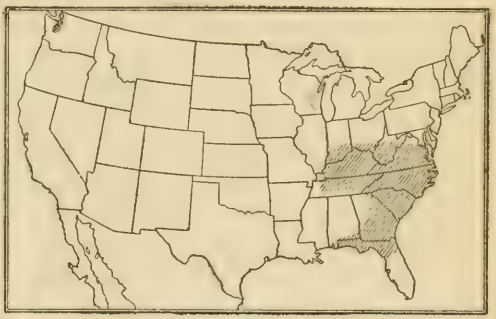

Fig. 1.—Map showing distribution of the tobacco hornworms in the United States.

NECESSITY AND ADVANTAGES OF THE USE OF AN INSECTICIDE.

The effect of the scarcity of labor in bringing about the use of an insecticide upon tobacco has already been explained. In addition to this necessity of using a poison, the much greater efficiency

Note.—This bulletin is intended to assist the tobacco growers of Kentucky and Tennessee and the adjoining States in combating a troublesome pest.

of a good application of an insecticide is another strong argument in its favor. Hand worming, even of the best, has many objections; for instance, eggs are not picked off, many small worms are overlooked, and, lastly, during the hot hours of the day large worms crawl down into the "ruffles" near the bases of the leaves, and a considerable number are thus overlooked. On the other hand, a thorough application of an insecticide will kill practically every hornworm—except those very nearly full grown—within two or three days, and will also continue to kill the young worms that hatch several days after the application. In short, hand picking has only an immediate effect in lessening the worms, whereas the application of an insecticide usually continues to kill over a period of several days. Cheapness is another point very greatly in favor of an insecticide as compared with hand picking. The cost of keeping an acre of tobacco hand wormed in a year when worms are plentiful is variously estimated at from $6 to $10. A like number of worms can be killed with Paris green at a cost of not more than $2 per acre, and with arsenate of lead at a cost of from $3 to $5 per acre.

INJURY TO TOBACCO BY THE USE OF PARIS GREEN.

Although Paris green has been in general use upon tobacco in many localities of Kentucky and Tennessee for more than a decade, yet, on account of its very frequent serious injury to tobacco, many growers use it only after it becomes too costly to keep the worms off the tobacco by hand picking. Occasionally dosages of 2 and even 2½ pounds are applied without visible injury. On the other hand, unfavorable weather conditions may cause dosages of 1 to 1½ pounds to burn seriously. In 1912 several fields in the vicinity of Clarksville, Tenn., were injured in amounts varying from 10 to 25 per cent of the gross value of the crop. The usual loss, however, is not greater than 4 or 5 per cent.

Paris green injures tobacco in two ways: First, by causing dead, burned areas upon the leaves, where the powder has been collected by the dews or washed down by the rains; second, by weakening the leaf at the stalk. Light rains wash the insecticide into the axils of the leaves, and the result is that many leaves drop off before cutting time or become so weakened that they drop off when the plant is cut. Although such leaves are not a total loss, for they are collected and cured, yet they are a partial loss, for they lack weight and elasticity.

ADVANTAGES OF THE USE OF ARSENATE OF LEAD.

Arsenate of lead causes none of the injury just mentioned. Experiments performed under the direction of the senior writer show that powdered arsenate of lead may be put on a fresh sucker wound

in large quantities without causing any noticeable injury, and that when applied to a torn or bruised leaf it produces no injury. Paris green can not be applied to tobacco in the "graining" stage (i. e., when nearly ripe) in sufficient quantities to do good insecticidal work without too grave danger of burning the plant. Arsenate of lead, on the other hand, can be safely applied to tobacco in the "graining" stage in quantities sufficient to produce satisfactory insecticidal results. Furthermore, arsenate of lead will cause no irritation to the operator as will Paris green; in fact, thus far it has produced no noticeable injurious effects upon the operators.

RESULTS THAT HAVE BEEN OBTAINED FROM THE USE OF ARSENATE OF LEAD.

APPLICATIONS IN FAIR WEATHER.

On August 24, 1910, Paris green was applied to a plat of tobacco at the rate of 1½ pounds per acre. On the third day after the application 95 per cent of the worms were dead. However, on the fifth day after the application numbers of small worms were seen upon the tobacco, which indicated that the dosage was losing its effect. On August 25, 1910, powdered arsenate of lead was applied, in the same field, to one plat at the rate of 5 pounds per acre and to another plat at the rate of 3½ pounds per acre. On the fourth day after the application about 99 per cent of the worms had been killed by the 5-pound dosage and about 89 per cent by the 3½-pound dosage. Both dosages of lead arsenate continued to kill worms for several days after the Paris green had lost its effect.

The foregoing applications were made under the most favorable conditions; that is, while dew was upon the plants and while there was no breeze. The tobacco was about two-thirds grown.

On August 21, 1911, a dosage of arsenate of lead at the rate of 4⅜ pounds per acre was applied during a breeze. At the expiration of four days only 78 per cent of the worms were dead. On the same date and under the same conditions an application of Paris green at the rate of 1¾ pounds per acre killed only 54 per cent of the worms in four days. These experiments emphasize the necessity of making the application of an insecticide when there is *very little breeze.*

APPLICATIONS IN RAINY WEATHER.

On August 28, 1911, arsenate of lead was applied about 7 a. m. to two plats of tobacco at the rates of 5 pounds and 4 pounds per acre, respectively, and Paris green was applied to the check plat at the rate of 2½ pounds per acre. The same day between 11 a. m. and 2 p. m. about one-third of an inch of rain fell in dashing showers. On the second day after the application 91 per cent of the worms had been killed by the 5-pound dosage of arsenate of lead, 83 per cent by the

4-pound dosage of arsenate of lead, and only 66 per cent by the 2½-pound dosage of Paris green. On the fourth day after the application the number of worms on the 5-pound dosage arsenate-of-lead plat was still further reduced. On the other hand, the worms had increased in numbers upon the 4-pound dosage arsenate-of-lead plat and on the Paris-green plat. These results indicate that arsenate of lead can be made effective under conditions under which Paris green is practically a failure.

EXPERIMENTAL ACRE AT CLARKSVILLE, TENN.

During the summer of 1913 an experimental acre of tobacco at Clarksville, Tenn., was kept free of worms by the use of powdered arsenate of lead from the time worms appeared in destructive numbers until worms ceased to appear. Four applications were made, using a total of 12¼ pounds, an average of a little more than 3 pounds per dosage. However, the first dosage was too light, only 2½ pounds, and had to be repeated. Had the first dosage been at the rate of about 4 pounds per acre, undoubtedly two more dosages of about 3½ pounds per acre would have been sufficient to do the work accomplished by the four applications. The total cost of the arsenate of lead and labor (assuming the arsenate of lead to retail at 25 cents per pound) was only $3.86, an average cost of 77 cents per week for the five weeks over which the dosages remained effective.

The first dosage was applied while the worms were small, and the repetition of the dosages at intervals of about 10 days prevented the growth of large worms. No hand worming was done upon this acre and no tobacco was injured either by the worms or by the arsenate of lead.

THE 4-ACRE FIELD AT PEMBROKE, KY.

On August 12, 1913, 4 acres of large tobacco upon the farm of Mr. R. Y. Pendleton, at Pembroke, Ky., were given an application of 5¼ pounds per acre of powdered arsenate of lead. At the time of the application the worms averaged two per plant. On August 14, or two days later, only four live worms were found on the entire field. The examination was made by walking across the field in opposite directions and examining numerous plants. There was no injury to the tobacco from poison burn. No more poison was applied to this field and practically no hand worming was necessary during the remainder of the season. This very remarkable result is explained in part by the fact that very little rain fell during August, and by the fact that comparatively few eggs were laid upon this tobacco after the middle of August. If worms had been numerous during the latter part of August and the weather rainy, undoubtedly another application would have been required.

The results upon this field emphasize the fact that a clean sweep of the tobacco worms can be made with arsenate of lead without danger of burning the tobacco. The tobacco in this field was well advanced and at a stage in which Paris-green burn was very likely to occur.

HOW TO APPLY ARSENATE OF LEAD TO TOBACCO.

Paris green is generally applied to tobacco by means of a dust gun and without the admixture of a carrier. On the other hand, arsenate of lead must be mixed with a carrier in order to secure an even and thorough distribution. Several carriers have been tested with this insecticide. Finely sifted air-slaked lime did not dust evenly. Road dust and land plaster proved to be too heavy. The best results were obtained with finely sifted, freshly burned wood ashes. At least an equal bulk of the wood ashes should be used. Mix the arsenate of lead and ashes very thoroughly and apply while there is dew upon the tobacco and when there is no breeze. Even if very dry and finely sifted ashes are used, unsatisfactory results will be obtained unless the application is made with a powerful dust gun. The hand-power dust guns now in general use do not furnish sufficient power to make anything like a satisfactory and effective application. Special guns that will perform satisfactory work are gradually coming on the market. The new guns have a fan with a diameter of 8 inches, whereas the old guns have a fan diameter of only 6 inches. The new guns have also an auxiliary dust chamber, which is very essential, because the dust containers of the old guns are so small that they have to be refilled five or six times for each acre dusted. Two refillings of the new guns will be sufficient for dusting an acre.

To secure the best results, dust the tobacco when dew is upon the plants and when there is no breeze. The use of a carrier that does not dust evenly, the application of the insecticide when there is too much breeze, and the use of too small a dust gun are all certain to give unsatisfactory results. Avoid these mistakes, and satisfactory results will be secured.

Thoroughness of application can not be too strongly recommended. When tobacco worms are numerous a poor application of an insecticide will miss worms enough to ruin in two days more than enough tobacco to pay for the whole application. Make the application thorough.

THE GRADE OF ARSENATE OF LEAD THAT SHOULD BE USED.

Arsenates of lead may be broadly divided into two forms, triplumbic and diplumbic. Theoretically the triplumbic form may contain 25.58 per cent of arsenic oxid, while the diplumbic may

contain 33.15 per cent of arsenic oxid. Experiments have shown that the triplumbic form is too slow in its insecticidal action to justify its use against tobacco hornworms. The diplumbic form is the one that should be used. *In order to be sure of receiving the diplumbic form, demand that the manufacturer and dealer guarantee that the arsenate of lead you buy contains at least 30 per cent of arsenic oxid* (As_2O_5) *in which not more than 1 per cent is free or water-soluble.* This grade was the one used in all the experiments mentioned in this bulletin. It is necessary to have a low percentage of free, or water-soluble, arsenic in order to insure against burning the tobacco.

WHEN TO APPLY ARSENATE OF LEAD.

The first application of arsenate of lead should be made when tobacco worms become too numerous to be kept off tobacco by the hand-picking that is usually done while hoeing, suckering, or topping tobacco. In some years a second and even a third application may be necessary. The time for making these applications will be indicated by the numbers of eggs and young worms appearing on the tobacco. For further discussion of this heading see figure 2.

DOSAGE OF ARSENATE OF LEAD REQUIRED.

When tobacco is small and has not begun to lap in the row an application of 3½ pounds of arsenate of lead per acre will be efficient if carefully made. Full-grown tobacco should receive not less than 5 pounds per acre. Of course the weight of the ashes or other carrier used is in addition to the weight of the arsenate of lead. In water spray use not less than 3 to 4 pounds per 100 gallons of water.

COST OF ARSENATE OF LEAD.

The special grade of powdered arsenate of lead recommended for use on tobacco will cost about 22 cents per pound at the factory in 100-pound kegs. The freight will be about 1 cent per pound, making the total cost 23 cents per pound to the grower. Therefore a 3½-pound dosage will cost about 80 cents, while a 5-pound dosage will cost $1.15. In 1913 powdered arsenate of lead retailed at Clarksville, Tenn., for 25 cents per pound. A 2-pound dosage of Paris green costs from 50 to 55 cents, while a dosage of 1¼ pounds, which is the smallest which should be applied, will cost about 31 to 35 cents. If the comparative cost of Paris green and arsenate of lead were the only question to be considered, it would be useless to recommend arsenate of lead. The cost, however, for the careful grower should be a matter of strictly secondary consideration. The certainty of not burning the tobacco should more than compensate for the extra cost of this insecticide.

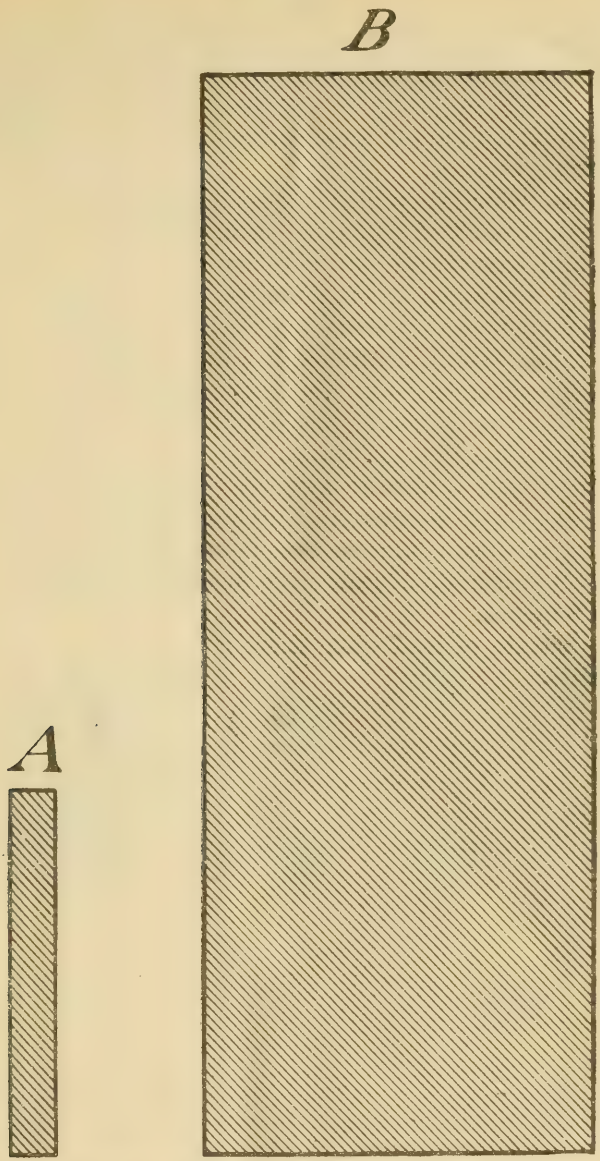

FIG. 2.—Amount of leaf surface of tobacco eaten by hornworms from time of hatching to completion of growth.

A represents one-sixteenth of the amount eaten in the first 9 days; *B* represents one-sixteenth of the amount eaten in the last 10 to 11 days.

During the first 9 days of its life the tobacco hornworm eats about $7\frac{2}{3}$ square inches of leaf surface, while during the last 10 to 11 days of its life it eats about $191\frac{1}{3}$ square inches—25 times the amount eaten during the first 9 days. *This statement should suggest the proper time for applying arsenate of lead to tobacco, which is while the worms are small—that is, while they are easy to kill and before they have done much damage to the tobacco.* Repeat the application as soon as numbers of small worms appear upon the tobacco.

SUMMARY.

Paris green frequently burns tobacco very severely, and may reduce the value of the crop as much as 50 per cent in exceptional cases.

It is impossible to apply an effective dosage of Paris green without risk of burning tobacco.

Paris green, which is applied in dust form without a carrier, is used at a dosage of from 1 to 2 pounds per acre.

Arsenate of lead is safe and effective during rainy weather, while Paris green is dangerous and ineffective.

It is recommended that arsenate of lead be used against the tobacco hornworms, and that it be applied as a dust or powder.

The dosage of arsenate of lead in powdered form varies from 3½ pounds per acre to 5 pounds per acre. If applied as a spray, use 3 to 4 pounds in 100 gallons of water.

Arsenate of lead applied in powdered form, as here recommended, must be mixed with a carrier. The best carrier found so far is dry wood ashes, used in a bulk at least equal to the arsenate of lead.

In applying arsenate of lead use a dust gun having a fan diameter of at least 8 inches.

Apply arsenate of lead when there is no breeze and when dew is on the plants.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1914

U.S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

626

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
December 2, 1914.

THE CARPET BEETLE OR "BUFFALO MOTH."[1]

By L. O. Howard,
Entomologist and Chief of Bureau.

GENERAL APPEARANCE AND METHOD OF WORK.

All the year around, in well-heated houses, but more frequently in summer and fall, an active brown larva a quarter of an inch or less in length and clothed with stiff brown hairs, which are longer around

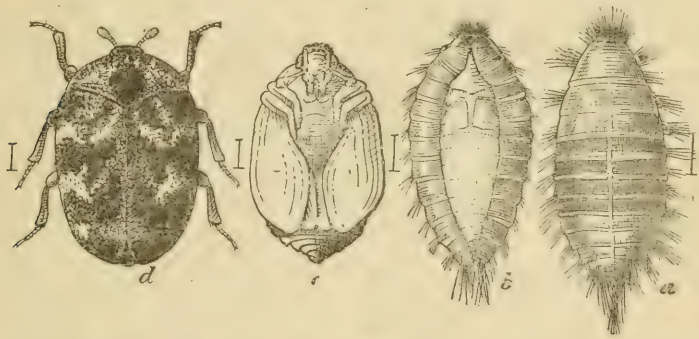

Fig. 1.—The carpet beetle (*Anthrenus scrophulariæ*): *a*, Larva, dorsal view; *b*, pupa within larval skin; *c*, pupa, ventral view; *d*, adult. All enlarged (from Riley).

the sides and still longer at the ends than on the back, feeds upon carpets and woolen goods, working in a hidden manner from the under surface, sometimes making irregular holes, but more frequently following the line of a floor crack and cutting long slits in a carpet.

DISTRIBUTION.

This insect in the United States is known as a carpet beetle only in the northern part of the country. It is not known as a carpet beetle in Washington or Baltimore, although in Washington and in places in the more southern States it has been occasionally met with during

[1] *Anthrenus scrophulariæ* L.; Order Coleoptera, Family Dermestidæ.

Note.—This bulletin is of interest to housewives in the Northern States.

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the past few years, both indoors and outdoors. In Philadelphia it is not common, but it abounds in New York, Boston, all the New England States, and west through Ohio, Indiana, Michigan, Wisconsin, Illinois, Iowa, and Kansas. It is originally a European insect, and is found in all parts of Europe. It was imported into this country about 1874,[1] probably almost simultaneously at New York and Boston. The *Anthrenus lepidus* of LeConte, from the Pacific coast, formerly considered as a variety of *scrophulariæ*, but now believed to be a distinct species, has not been found to attack carpets so far as known.

NATURAL HISTORY AND HABITS.

The adult insect is a minute, broad-oval beetle, about three-sixteenths of an inch long, black in color, but covered with exceedingly minute scales, which give it a marbled black-and-white appearance. It has also a red stripe down the middle of the back, widening into projections at three intervals. When disturbed it "plays 'possum," folding up its legs and antennæ and feigning death. As a general thing the beetles begin to appear in the fall, and continue to issue, in heated houses, throughout the winter and following spring. Soon after issuing they pair, and the females lay their eggs in convenient spots. The eggs hatch, under favorable conditions, in a few days, and the larvæ, with plenty of food, develop quite rapidly. Their development is retarded by cold weather or by lack of food, and they remain alive in the larval state, under such conditions, and particularly in dry atmosphere, for an almost indefinite period, molting frequently and feeding upon their cast skins. Under normal conditions, however, the skin is cast about six times, and there are probably in the North not more than two generations annually. When the larva reaches full growth the yellowish pupa is formed within the last larval skin. Eventually this skin splits down the back and reveals the pupa, from which the beetle emerges later. The beetles are day-flyers and when not engaged in egg-laying are attracted to the light. They fly to the windows and may often be found upon the sills or panes. Where they can fly out through an open window they do so, and they are strongly attracted to the flowers of certain plants, particularly of the family Scrophulariaceæ, but also to certain Compositæ, such as milfoil. The flowers of Spiræa are also strongly attractive to the beetles. It is probable, however, that this migration from the house takes place, under ordinary circumstances, after the eggs have been laid.

In Europe the insect is not especially noted as a household pest; this is probably owing to the fact that carpets are little used. In fact it is believed that only where carpets are extensively used are

[1] Prof. Samuel Henshaw has recorded it from Boston, Mass., as early as 1869. (Psyche, v. 6, p. 372, January, 1893.

the conditions favorable for the great increase of the insect. Carpets once put down are seldom taken up for a year, and in the meantime the insect develops uninterruptedly. Where there are polished floors and where rugs are used, or straw mattings and rugs, the rugs are often taken up and beaten, and in the same way woolens and furs are never allowed to remain undisturbed for an entire year. It is a well-known fact that the carpet habit is a bad one from other points of view, and there is little doubt that as carpets become more and more discarded in the Northern States the "Buffalo bug" will eventually cease to be a household insect of importance. The insect is known in Europe as a museum pest, but has not acquired this habit to any great extent in this country. It is known to have this habit in Cambridge, Mass., and Detroit, Mich., as well as in San Francisco, Cal., but not in other localities. In all of these three cases it has been imported from Europe in insect collections.

REMEDIES.

THOROUGH HOUSE CLEANING.

There is no easy way to keep the carpet beetle in check. When it has once taken possession of a house nothing but the most thorough and long-continued measures will eradicate it. The practice of house-cleaning but once annually, so often carelessly and hurriedly performed, is, as shown above, peculiarly favorable to the development of the insect. Two house cleanings would be better than one, and if but one, it would be better to undertake it in midsummer than at any other time of the year. Where convenience or conservatism demands an adherence to the old custom, however, there must be extreme thoroughness and a slight variation in the customary methods. The rooms should be attended to one or two at a time. The carpets should be taken up, thoroughly beaten, and sprayed out of doors with benzine, and allowed to air for several hours. The rooms themselves should be thoroughly swept and dusted, the floors washed down with hot water, the cracks carefully cleaned out, and kerosene or benzine poured into the cracks and sprayed under the baseboards. *The extreme inflammability of benzine, and even of its vapor when confined, should be remembered and fire carefully guarded against.* Where the floors are poorly constructed and the cracks are wide, it will be a good idea to fill the cracks with plaster of Paris in a liquid state; this will afterwards set and lessen the number of harboring places for the insect. Before relaying the carpet, tarred roofing paper should be laid upon the floor, at least around the edges, but preferably over the entire surface, and when the carpet is relaid it will be well to tack it down rather lightly, so that it can be occasionally lifted at the edges and examined for the presence of the insect. Later in the season,

if such an examination shows the insect to have made its appearance, a good though somewhat laborious remedy consists in laying a damp cloth smoothly over the suspected spot of the carpet and ironing it with a hot iron. The steam thus generated will pass through the carpet and kill the insects immediately beneath it.

BISULPHID OF CARBON.

An effective method of ridding the premises of carpet beetles as well as other household insects consists in fumigation with bisulphid of carbon vapor. Owing to the extremely inflammable nature of the gas great care should be taken that there is no fire in the house when the fumigation is in process. The inhaling of the vapor should also be avoided.

THE HYDROCYANIC-ACID GAS TREATMENT.

Hydrocyanic acid gas has for the past ten years been used to exterminate household insect pests and other vermin, and is the most effective remedy known for this purpose. *It must be used, however, with the greatest caution, as it is extremely poisonous and deadly to human beings as well as to the lower forms of animal life.* Great care must be exercised also in handling the poisonous chemicals—potassium cyanid and sulphuric acid—used in generating the gas. Circular No. 163 of the Bureau of Entomology, U. S. Department of Agriculture, explains fully the method of use, and this should be studied well before the treatment is undertaken.

SULPHUR DIOXID.

The fumes of burning sulphur, consisting of sulphur dioxid with some sulphur trioxid, have been in use for many years for the destruction of insect pests of the household, notably the bedbug, and will undoubtedly kill the carpet beetle as well if the fumigation is thorough. Its use is explained on pages 44 and 45 of Farmers' Bulletin 127, Second Revision, of this Department.

PREVENTIVES.

The only hope of the good housekeeper where the system of heavy carpets covering the entire floor surface is adhered to, lies in the strenuous measures explained in the foregoing paragraphs. Good housekeepers are conservative people, but there may eventually be expected a general adoption of the rug or of the square of carpet, which may be readily examined at all times and treated if found necessary. Where the floors are bad the practice of laying straw mattings under the rugs produces a sightly appearance, and, while not as cleanly as a bare floor, affords still fewer harboring places for this insect.

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U.S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

627

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
December 15, 1914.

THE HOUSE CENTIPEDE.[1]

By C. L. Marlatt,
Entomologist and Assistant Chief of Bureau.

GENERAL APPEARANCE AND HABITS.

The house centipede (fig. 1), particularly within the last 20 or 25 years, has become altogether too common an object in dwelling houses in the Middle and Northern States for the peace of mind of the inmates. It is a very fragile creature capable of very rapid movements, and elevated considerably above the surface upon which it runs by very numerous long legs. It may often be seen darting across floors with very great speed, occasionally stopping suddenly and remaining absolutely motionless, presently to resume its rapid movements, often darting directly at inmates of the house, particularly women, evidently with a desire to conceal itself beneath their dresses, and thus creating much consternation. The creature is not a true insect, but belongs to the Myriapoda, commonly known as centipedes or "thousand legs," and is sometimes called the "skein" centipede, from the fact that when crushed or motionless it looks, from its numerous long legs, like a mass of filaments or threads. It is a creature of the damp, and is particularly abundant in bathrooms, moist closets, and cellars, multiplying excessively also in conservatories, especially about places where pots are stored, and near heating pipes. In houses it will often be dislodged from behind furniture or be seen to run rapidly across the room, either in search of food or concealment. If examined closely its very cleanly habits may occasionally be manifested in that it may be observed to pass its long legs, one after another, through its mandibles, to remove any adhering dust. Its rather weird appearance, its peculiar manner of locomotion, and frequently its altogether too friendly way of approaching people, give it great interest, and with its increasing abundance in the North, make it a subject of frequent inquiry.

Note.—This bulletin is of interest to housewives throughout the United States. It is a reprint of Bureau of Entomology Circular 48.

[1] *Scutigera forceps* Raf.

FORMER AND PRESENT DISTRIBUTION.

The house centipede is a Southern species, its normal habitat being in the southern tier of States and southwestward through Texas into Mexico. It has slowly spread northward, having been observed in Pennsylvania as early as 1849, and reaching New York and Massachusetts 30 or 35 years ago, but for many years after its first appearance in the latter two States it was of rare occurrence. It is now very common throughout New York and the New England States, and extends westward well beyond the Mississippi, probably to the mountains.

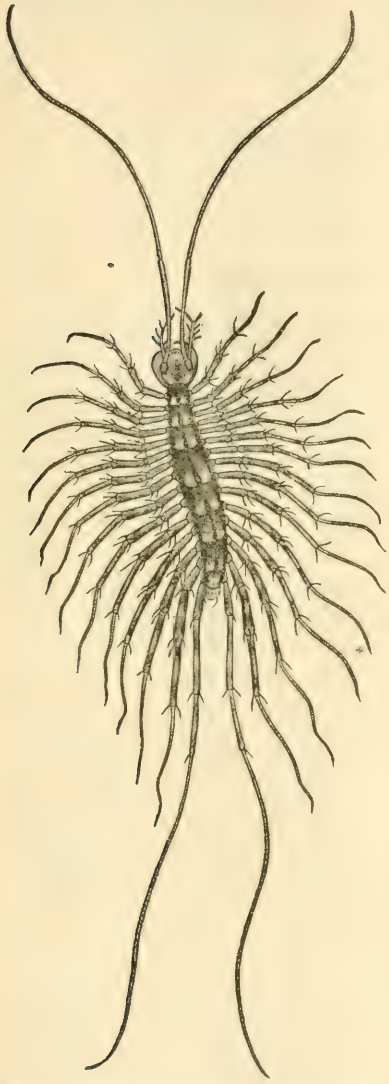

FIG. 1.—The house centipede (*Scutigera forceps*): Adult. Natural size. (Author's illustration.)

DESCRIPTION AND FOOD HABITS.

It is a very delicate creature, and it is almost impossible to catch it, even should one desire to do so, without dismembering several of its numerous legs, or crushing it. If captured, so that it can be more readily examined, it will be found to consist of a worm-like body of an inch or a little more in length, armed at the head with a pair of very long, slender antennæ, and along the sides with a fringe of fifteen pairs of long legs. The last pair is much longer than the others, in the female more than twice the length of the body. In color it is of a grayish yellow, marked above with three longitudinal dark stripes. Examination of its mouth parts shows that they are very powerful, and fitted for biting, indicating a predatory or carnivorous habit.

The indications of its mouth parts are borne out by its food habits, besides being indicated by the known food habits of the other members of the group of centipedes to which it belongs. It was inferred, before any direct observations were made, that its food was probably house flies, roaches, and any other insect inhabitants of dwellings.

Later many direct observations have confirmed this inference, and in captivity, on the authority of Prof. Hargitt, it feeds readily on roaches, house flies, and other insects. Miss Murtfeldt reports also having observed specimens devouring small moths. During the act of devouring a moth they kept their numerous long legs vibrating with incredible swiftness, so as to give the appearance of a hazy spot or space surrounding the fluttering moth.[1] It is supposed also to feed on the bedbug, and doubtless will eat any insect which it captures, and its quickness and agility leave few insects safe from it.

Fletcher and Howard have observed its mode of capturing the croton bug, which is interesting as illustrating the habits of this centipede and its allies. In this instance the centipede sprang over its prey, inclosing and caging it with its many legs. In its habit of springing after its prey this centipede is similar to spiders, which it also resembles in its rapacious habits. It would therefore seem to be a very efficient enemy of many of our house pests. The common idea that it probably feeds on household goods and woolens or other clothing has no basis in fact.

THE BITE OF THE HOUSE CENTIPEDE.

The popular belief is that this centipede is extremely poisonous, and, as it belongs with the poisonous group of centipedes, it can not be questioned but that the bite of the creature is probably somewhat poisonous as well as painful, though the seriousness of the results will be dependent, as in all similar cases, on the susceptibility of the patient. The poison injected in the act of biting is probably merely to assist in numbing and quieting its victim, and in spite of its abundance in houses in the North, and for many years its much greater abundance in the South, very few cases are recorded of its having bitten any human being, and it is very questionable whether it would ever, unprovoked, attack any large animal. If pressed with the bare foot or hand, or if caught between sheets in beds, this, like almost any other insect, will unquestionably bite in self-defense, and the few cases on record indicate that severe swelling and pain may result from the poison injected. Prompt dressing of the wound with ammonia will greatly alleviate the disagreeable symptoms.

THE EARLY STAGES OF THE CENTIPEDE.

Little is known of the early life history of this myriapod. It is found in the adult state in houses during practically the entire year. Half-grown individuals are also found frequently during the summer. A newly-born specimen, found by H. G. Hubbard in the insectary

[1] Murtfeldt, Mary E. Entomological Memoranda for 1893. U. S. Dept. Agr., Div. Ent., Insect Life, vol. 6, No. 3, p. 257-259, February, 1894. "*Scutigera forceps* and Callimorpha," p. 258.

of the United States Department of Agriculture under a moist section of a log, differed from the older forms chiefly in possessing fewer legs. Its characteristics are indicated in figure 2. A very interesting feature of this specimen is that the terminal segment of the body contains the long posterior legs folded up within it as indicated at figure 2, *c*. They are doubtless liberated at the next molting. In the half-grown and later stages this centipede does not differ materially from the adult, except in size, and its habits throughout life are probably subject to little variation.

REMEDIES.

If it were not for its uncanny appearance, which is hardly calculated to inspire confidence, especially when it is darting at one with great

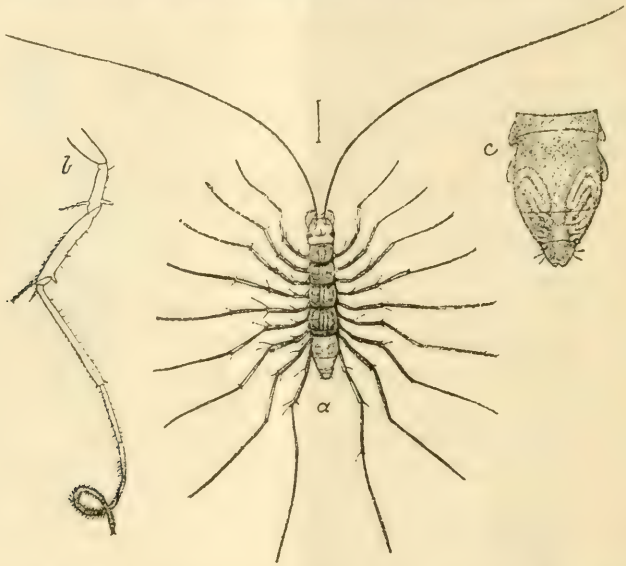

FIG. 2.—The house centipede: *a*. Newly hatched individual; *b*, one of legs of same; *c*, terminal segment of body showing undeveloped legs coiled up within. All enlarged. (Author's illustration.)

speed, and the rather poisonous nature of its bite, it would not necessarily be an unwelcome visitor in houses, but, on the contrary, might be looked upon rather as an aid in keeping in check various household pests. Its appearance in dwellings, however, will not often be welcomed notwithstanding its useful rôle. It can be best controlled by promptly destroying all the individuals which make their appearance, and by keeping the moist places in houses free from any object behind which it can conceal itself, or at least subjecting such locations to frequent inspection. In places near water pipes, or in storerooms where it may secrete itself and occur in some numbers, a free use of fresh pyrethrum powder is to be advised.

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U.S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

634

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

December 7, 1914.

THE LARGER CORN STALK-BORER.[1]

By George G. Ainslie,

Entomological Assistant, Cereal and Forage Insect Investigations.

INTRODUCTION.

In many Southern cornfields a heavy wind late in the season, before the corn is matured, does great damage by breaking the plants off at the surface of the ground, thus ruining them. An examination of these broken stems will, in most cases, show that they have been greatly weakened by the burrows of a larva or caterpillar. This larva (fig. 1) is known as "the larger corn stalk-borer." Its work is largely within the stem of the plant and is so concealed that in most cases, unless weather conditions make it conspicuous, the presence of the insect passes unnoticed.

Fig. 1.—The larger corn stalk-borer: *a*, Summer form of larva; *b*, *c*, hibernating forms of larvæ; *d*, third thoracic segment from above; *e*, eighth abdominal segment from above; *f*, abdominal segment from above; *g*, same from side. *a*, *b*, *c*, Enlarged; *d*, *e*, *f*, still more enlarged. (Redrawn from Howard.)

This insect seems to have been originally an enemy of sugar cane and to have first transferred its attention to corn, in the southern part of this country, where corn and cane are grown over the same territory. It occurs in many countries where sugar cane is the staple crop, and has caused great damage in the West Indies, British Guiana, Australia, and Java. The bulk of the evidence goes to show that it was first brought into this country with the importation of sugar-cane cuttings from the West Indies and Central and South America, where, since early times, it has interfered with the production of this staple.

[1] *Diatræa saccharalis* Fab.

In the United States this borer is found almost universally throughout the South, from Maryland to Louisiana and westward to Kansas. Among other localities it has been reported from Bennettsville, S. C., as destroying corn, especially that planted early in the season. From Waynesboro, Ga., in 1909, reports were received that in some fields the corn was "at least one-third destroyed" by an insect which later proved to be this species. In Virginia it has been found recently at Nathalie, at Allensleyel, at Church Road, and at Farmville. In late October, 1909, Mr. E. G. Smyth found that nearly one-half of the cornstalks at Diamond Springs, Va., were infested, often as many as three larvæ being found in one stalk, boring from the surface of the ground down to the base of the root; and while the author has frequently found as many as a dozen larvæ in a single stalk, there are never more than two or three pupæ in the same stalk. In each case it had damaged the corn, and especially that planted early in the season.

NATURE OF DAMAGE.

Corn is damaged by these caterpillars in two ways. First, in the early part of the season, while the plants are small, they work in the "throat" of the young corn, and if the tender growing tip within the protecting leaves is once damaged, all chances that the plant will become a normal productive specimen are gone. In many sections of the South this is commonly known as "bud-worm" injury, and though there are several other insects which cause a similar mutilation of the leaf, a very large proportion of the so-called "bud-worm" damage may be charged to this insect. The effect of its work on the leaves of the young corn plants is similar to that resulting from attacks by the corn billbugs and is evidenced by the familiar rows of small circular or irregular holes across the blades of the plant (fig. 2).

The other form of serious damage chargeable to this pest occurs later in the season. The larvæ, having then left the leaves and descended to the lower part of the stalk, tunnel in the pith. (See fig. 3.) If the larvæ are at all numerous in the stalk, their burrows so weaken the plant that any unusual strain will lay it low and destroy all chance of its maturing. While frequently ten or more larvæ may live and mature in one plant, it must be remembered that any infestation, however light, will lessen in some degree the vitality of the plant and cause a corresponding loss in the quality and quantity of the harvest.

HABITS OF THE LARVÆ.

Immediately upon leaving the egg in spring, the young larva of the first generation, spinning a silken thread behind it, wanders down into the throat of the plant as far as the water or dew usually standing there will allow it to go, and begins to feed on the leaves, going back and forth through the yet unfolded clusters and soon

riddling the more tender leaves with aimless burrows. If the burrow reaches the tender terminal bud where the future joints are being formed, further growth at that point ceases and the plant becomes stunted and misshapen, with no tassel. As the plant continues to mature, the larva "grows out," as the farmers say. It is more likely that it is not the larva itself but the evidences of its work that "grow out"; but for whatever reason, the caterpillar soon leaves the more leafy portion of the plant and attacks the stalk at or near the ground. Here a hole is cut through the outer wall of the stalk

FIG. 2.—Work of larger corn stalk-borer, showing mutilation of leaves of corn by larvæ. Greatly reduced. (Author's illustration.)

and the larva burrows upward for a short distance, after which it seems to run aimlessly through the pith, frequently even leaving the stalk entirely and reentering it at another point. Turning upward, the caterpillar, when fully grown, bores toward the outside and cuts a circular hole in the outer wall of the stalk. Then, after spinning a few loose threads across this opening to keep out undesirable visitors, it retreats a short distance, plugs the burrow below with digested pith, and in the chamber thus created slowly changes to the next or pupal stage (fig. 4, *c*).

Seldom is the stalk damaged above the third joint from the ground, although the larvæ, when small, are found in the large midribs of the lower leaves and later in the season, when the food supply is restricted, even in succulent nubbins farther up. They sometimes also penetrate the underground part of the stalk in feeding and enter some of the larger brace roots for a short distance.

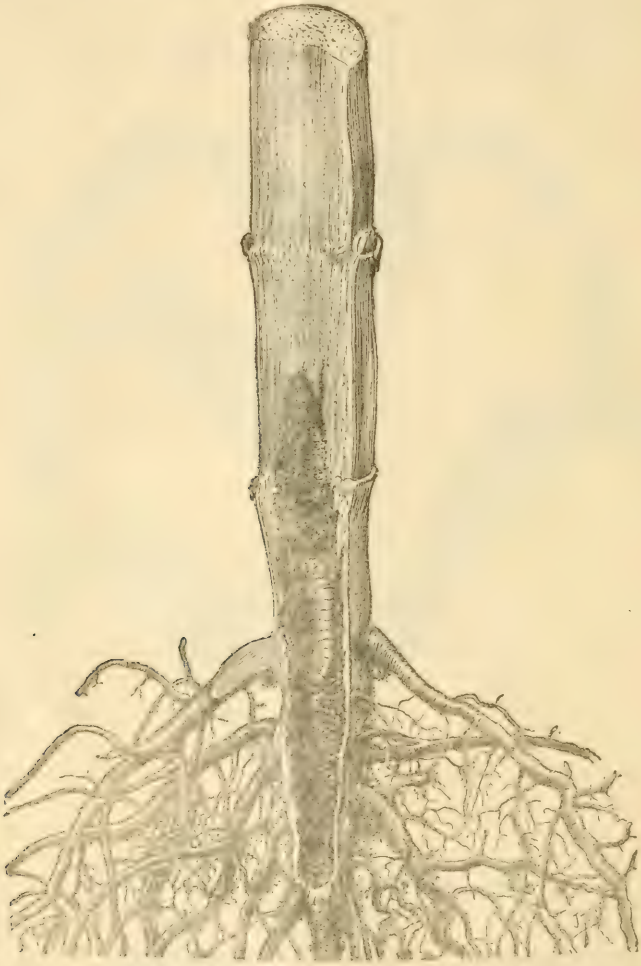

FIG. 3.—The larger corn stalk-borer: Larva in lower part of corn plant preparatory to hibernation. Reduced. (Author's illustration.)

The larvæ of the second generation work in a similar manner, except that at the time they appear the tassel has been formed; hence the damage is now confined altogether to the lower stalk. Thus, instead of arranging to pass the pupal stage in the upper stalk, they penetrate to the root to hibernate and there, as larvæ, pass the winter in a quiescent state (fig. 3).

SEASONAL HISTORY.

During the winter this enemy of corn is to be found as a robust, creamy-white larva of the second generation in the lower part of the stalk or of the stubble, if, as is usually the case, the corn has been cut. In this location the larva forms a small cavity below the surface of the ground, well protected from birds, predaceous insects, and unfavorable weather conditions. From the time the corn is mature in the fall until about corn-planting time in the spring this caterpillar remains inactive. About the time the ground is being prepared for corn, from March 15 to April 30, depending on the locality, this larva changes into a reddish-brown pupa or chrysalis (fig. 4, *c*). After a further period of 10 or more days' inactivity the adult insect emerges from the pupa case as a pale brownish-yellow moth (fig. 4, *a*), with a spread of wings of about an inch and a fourth. The moths then mate, and the females begin at once to deposit eggs on the underside of the leaves, the larvæ hatching from these eggs forming the first generation.

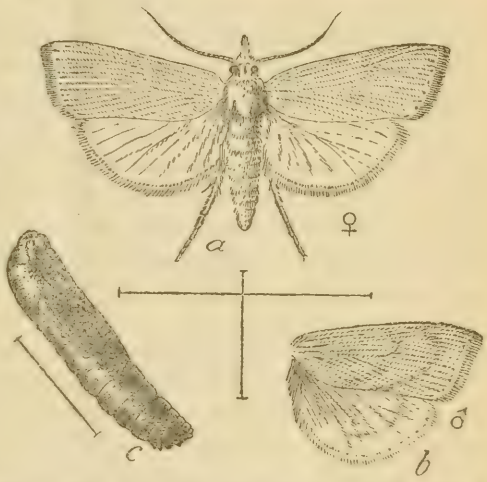

FIG. 4.—The larger corn stalk-borer: *a*, Female moth; *b*, wings of male; *c*, pupa. All somewhat enlarged. (Author's illustration.)

The eggs hatch in from 7 to 10 days and the young larvæ begin their destructive work in the upper leafy portion of the plant, later descending to the base of the stalk, where they attain full growth. This period, from egg to full-grown larva, requires from 20 to 30 days, depending largely on the weather conditions and the vigor of the plant. The larvæ when full grown pupate in the stalk, usually in the second or third joint from the ground, and in from 7 to 10 days the adult moths of the first generation emerge.

The eggs for the second generation are laid in similar positions on the lower leaves or on the stem, and the larvæ, after feeding for a short time on the leaves, go directly to work in the stalk, completing their larval growth in the pith of the lower stalk as did the larvæ of the first generation. No damage is done to the upper part of the plant by larvæ of the second generation.

By the time the larvæ of the second generation are full grown the corn is rapidly nearing maturity, and, instead of pupating in

the stalk, they turn downward, penetrate to the extreme lower tip of the taproot, and there form a small cavity in which to pass the winter. At this time the larvæ lose the darker markings of the earlier forms, and as overwintering larvæ are creamy-yellow in color. They are plump and active in the fall, but flabby and sluggish after fasting throughout the winter. The only way in which the insect passes the winter is in the form of this overwintering larva, found below the ground in the extreme lower tip of the corn roots. Two generations a year appear to be the rule, although it is possible that in the far South and on sugar cane a partial third generation may occur.

DESCRIPTIONS.

EGG.

The eggs are flat and scalelike, almost circular in outline, and are placed in rows or irregularly, overlapping one another shingle fashion. From 2 to 25 eggs are laid in one place on the underside of a lower leaf or occasionally on the upper side and on the stem. Creamy-white when first laid, they gradually change to a reddish-brown, and in 7 to 10 days a minute, bristly, reddish caterpillar cracks the shell and crawls out through a narrow slit at one end. The eggs are about three one-hundredths of an inch (7.6 mm.) long and about two-thirds as wide. After hatching, the white papery shells are soon washed off the leaves.

LARVA.

The larva of the first generation (fig. 1, *a*) when full grown is a robust, dirty-white caterpillar 1 inch in length, thickly covered with round or irregular dark spots, each of which bears a short, dark bristle. When the larva is small these markings are almost contiguous, giving the whole insect a dark color and a hairy appearance. The head and thoracic plate of all the stages are brownish-yellow. The overwintering larva of the second generation (fig. 1, *b*, *c*) gradually loses the darker markings of the body and after the last molt remains unspotted and light yellow in color, except for the head and the thoracic plate, which retain the brownish-yellow of the earlier stages.

PUPA.

When first formed, the pupa (fig. 4, *c*) is light honey-yellow in color, soon changing to a rich mahogany-brown. It is about seven-eighths of an inch in length and is able to contort itself violently when disturbed. It lies in the cavity, usually with the head up. On emerging, the moth leaves the brownish shell of the pupa case partially withdrawn from the hole.

ADULT.

The female moth (fig. 4, *a*) varies in color from almost white to smoky yellow. The fore wings, which spread to about 1¼ inches,

are darker than the hind wings, and bear faint markings. When at rest the wings are held close to the body, forming an acute triangle. The egg laying is done for the most part either at night or in the dusk of evening, the moths flying rapidly from plant to plant. The male moth is usually somewhat darker in color than the female and always smaller.

FOOD PLANTS.

Besides corn and sugar cane, this borer has been reported as feeding on sorghum, Johnson grass, guinea corn, and grama grass. The injury to the four last-mentioned plants is never severe, but in planning methods of control they must be considered and an examination made to determine whether or not they are harboring the pest.

NATURAL CHECKS.

The larger corn stalk-borer has very few natural enemies. A minute hymenopterous parasite[1] has in a very few instances been found living in and destroying the eggs. In one case 10 of these minute parasites were reared from two eggs. The larva of a brown velvety beetle[2] sometimes enters the holes in the stalks of stubble after the corn is cut and devours the caterpillars found therein. This larva has been found to be of great value in reducing the numbers of the borers in fields of sugar cane. The termites or white ants,[3] locally known as "wood lice," have been observed destroying the larvæ in the stubble in the winter, although apparently only when the presence of the larvæ interfered with the work of the ants. In a few cases bodies of the borers have been found in the stubble killed by a fungus, as yet undetermined, which envelops their bodies in a white mold. Fungi, however, are too dependent on weather conditions to be of any practical value in controlling the pest.

PREVENTIVE MEASURES.

Rotation is one of the best general preventives of injury from insects affecting field crops. Experience has shown that where corn has followed itself upon the same field for two or more years there has been a much greater loss from the borer than where an annual change of crop has been practiced. This is especially noticeable where stalks or stubble from the previous year have been allowed to remain undisturbed throughout the winter. The moths, upon emergence in the spring, finding themselves surrounded by the young corn, commence egg laying at once, and escape the dangers encountered in searching for another field of corn. A forced journey in search of young corn results in many of the females being eaten by birds or being destroyed because of rain, cold, or failure to find the object of their quest. A few moths will always succeed in their search, but the

[1] *Trichogramma pretiosa* Riley.
[2] *Chauliognathus pennsylvanicus* De G.
[3] *Leucotermes* spp.

successful proportion will be greatly decreased by persistent crop rotation.

Another remedy, probably the best for this insect, is the thorough destruction, some time before the period of emergence of the moths in the spring, of all the stalks and stubble remaining in the field from the preceding crop. If all this trash can be disposed of before the opening of spring, the numbers of the pest must be greatly diminished if not almost exterminated, for the only form in which the insect passes the winter is that of the caterpillar, and the only known location is in the lower tip of the corn root, snugly hidden. Some few may, however, be found to survive in the roots of the larger grasses mentioned above, and care should be taken in such cases to treat these in the same way. The method employed in disposing of the stubble and stalks will depend largely on the conditions in individual cases. If the stubble is cut low and the land is moderately heavy, a thorough deep plowing may suffice, an inch or two of well-settled soil being sufficient to prevent the escape of the adult moths. Bringing the stubble to the surface where it can dry will kill some of the contained larvæ, but this method depends too much on the state of the weather to be trusted. By far the most effective plan is to remove the stubble from the field with a rake and burn it.

In the cane field the methods of treatment must be adjusted to correspond with the methods of handling that crop. The larvæ commonly spend the winter in the trimmings and tops which have been discarded at harvest time because of immaturity. This refuse, left on the ground throughout the winter, becomes dry and inflammable and, if thoroughly burned before spring, enough larvæ will be killed to insure at least temporary relief from the ravages of the borer.

Any method which will insure the complete destruction of the overwintering larvæ, if persisted in and carried out simultaneously over large sections of the country, will effectually preclude serious damage from the insect.

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U.S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

636

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
December 31, 1914.

THE CHALCIS-FLY IN ALFALFA SEED.

By Theodore D. Urbahns.
Entomological Assistant, Cereal and Forage Insect Investigations.

INTRODUCTION.

The clover-seed chalcis-fly [1] (fig. 1), which is generally termed the alfalfa-seed chalcis-fly by alfalfa-seed growers, has been increasing

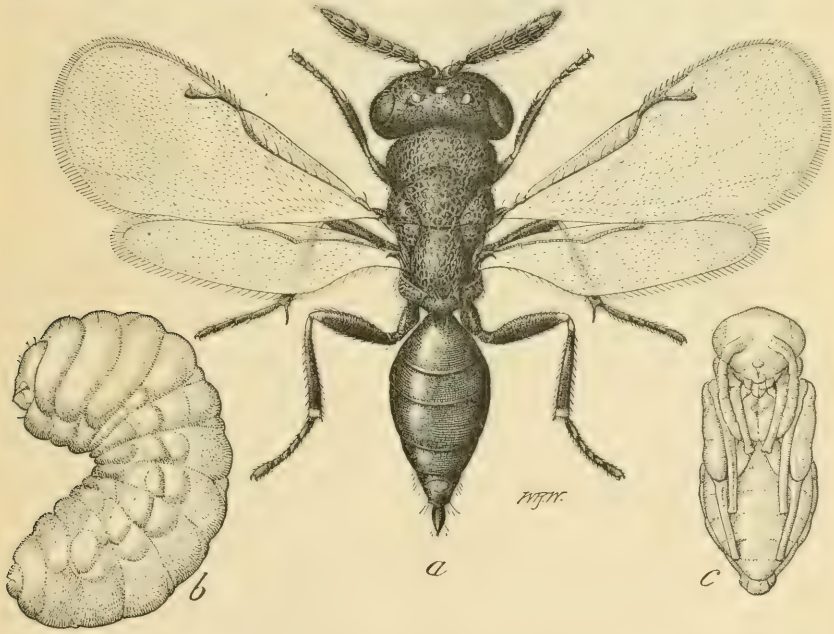

Fig. 1.—The alfalfa-seed, or clover-seed, chalcis-fly: *a*, Adult; *b*, larva; *c*, pupa. Much enlarged. (Original.)

so rapidly that its destructive work is now causing a large annual loss, and in some sections even threatening the production of alfalfa seed.

[1] Scientific name, *Bruchophagus funebris* How.

Note.—This bulletin furnishes a general knowledge of the chalcis-fly, an insect injurious to alfalfa seed, and contains several practical methods for its control.

In the fall of 1912 an investigation was started with a view to determining some practical method of checking this pest. Much of this work is still in an experimental stage, but certain practices are at hand whereby the grower of alfalfa seed may reduce the numbers of this insect in his fields and without doubt profit largely by the results.

The different sections in which investigations have been conducted present in themselves many local problems which must necessarily be omitted in this brief preliminary account of an insect which is so widely distributed and so destructive. Nevertheless this bulletin will serve to give the alfalfa-seed grower a general knowledge of the chalcis-fly, together with such information as will direct him in adopting measures for reducing the large annual loss due to its work.

DEVELOPMENT AND HABITS.

The eggs are very small; in fact, they are invisible to the naked eye, and are deposited through the soft green seed pods directly into the soft seeds. Under field conditions oviposition usually takes place when the pods are about half grown. The time required for the eggs to hatch varies greatly. Under favorable temperatures the larvæ (fig. 1, *b*) begin feeding in about a week after the eggs have been deposited. The larvæ feed within the soft, tender, growing seeds, and before the pods have had time to ripen most of them have become full grown.

When there is sufficient moisture remaining in the seed pods, most of the larvæ at once transform to the pupal stage, but if the seeds become thoroughly dry before the larvæ enter the pupal stage (fig. 1, *c*) this transformation may be delayed indefinitely and the larvæ remain dormant until the following spring or some other time when both moisture and temperature are favorable for their transformation. In the pupal stage the insect may rest from 10 to 40 days before emerging as an adult.

All of the stages of development are completed within the infested seeds.

Immediately upon becoming adult (fig. 1, *a*) the chalcis-flies eat their way out through the remaining shells of the infested seeds, then through the seed pods (fig. 3), leaving in each case a hollow seed (fig. 2). The adults may be seen in great numbers flying over alfalfa-seed shocks and swarming over the sickle bar when the crop is being cut. They are frequently confused with gnats.

The chalcis-flies are most active in hot weather, but seek the shade in the heat of the day. They visit the alfalfa blossoms apparently to secure food, and in moderate weather live to be several weeks old.

FLIGHT.

The adults of the chalcis-fly are very active in their flight and without doubt are carried long distances by the strong summer winds. They have been observed in great numbers carried by the winds on a hot summer day, alighting on almost any object in their course.

HIBERNATION.

The chalcis-fly hibernates in the larval stage within alfalfa seeds. By far the greater number may be found in the seeds on neglected fields (fig. 9) and along fence lines and ditch banks (figs. 6, 7). A great many seed pods may be found on the surface of fields from which the seed crops have been removed, and especially along the check ridges where alfalfa frequently remains standing. Screenings around the alfalfa straw stacks (fig. 8) and the seed of bur clover[1] conceal many of the larvæ.

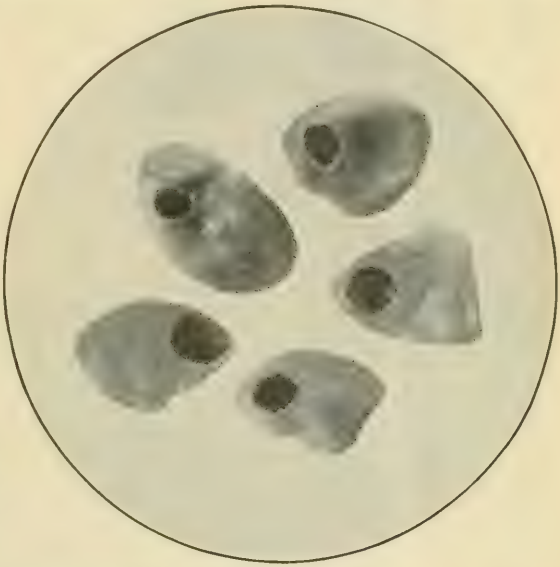

FIG. 2.—Alfalfa seeds which have been hollowed out by the larvæ and from which the adult chalcis-flies have emerged. (Original.)

DISTRIBUTION.

In Circular 69,[2] Mr. F. M. Webster shows the distribution of the alfalfa-seed chalcis as probably covering the entire United States.

The writer has personally observed its destructive work in clover or alfalfa seeds from the Gulf coast to the northern limits of the United States, as well as in the southwestern States. Injury from this insect has been observed in cultivated alfalfa seed imported from Germany, Turkestan, and Chile, and in both the cultivated and uncultivated varieties of alfalfa seed from Turkey and Siberia.

CHARACTER OF INJURY.

The clover-seed chalcis-fly confines its work entirely to the seeds of clover, bur clover,[1] and alfalfa. Its destructive work results in the hollowing out of large portions of the seeds while still soft and green

[1] Scientific name, *Medicago hispida*.

[2] Webster, F. M. Some insects affecting the production of red clover seed. U. S. Dept. Agr., Bur. Ent. Circ. 69, pp. 9, figs. 8, Apr. 12, 1906.

and growing in the fields. (See fig. 2.) The percentage of aborted and worthless seeds is increased by infestation before they are large enough to supply the growing larvæ with food. In such cases both the larvæ and seeds are prematurely destroyed.

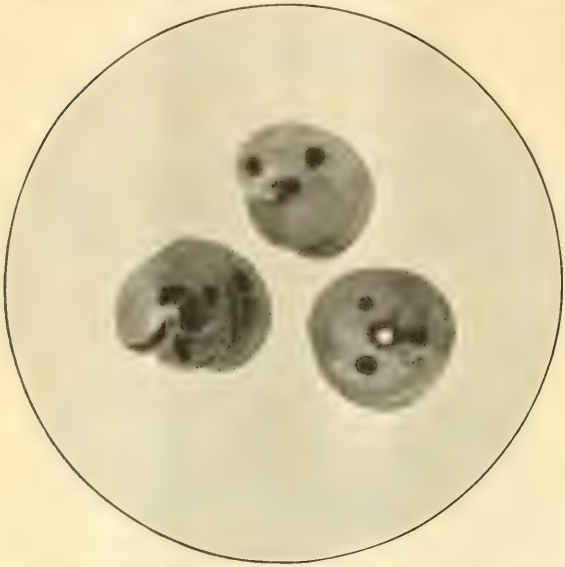

FIG. 3.—Alfalfa seed pods, showing the openings made by the adult chalcis-flies as each escaped from a seed within. (Original.)

When the adults of the chalcis-fly emerge normally from the alfalfa seeds they leave nothing but the hollow shell (fig. 2), with the opening from which the adult has escaped near one end. A similar opening is left in the seed pods, directly over that in the seed (fig. 3). The infested seeds which still contain the living larvæ of the insect may be recognized by their abnormal shape (fig. 4), and usually by the dull brown color. Some of the infested seeds, however, retain their natural color, but they always lack the glossy appearance of normal seeds.

FIG. 4.—Infested alfalfa seeds which contained the hibernating larvæ of the chalcis-fly. (Original.)

EXTENT OF INJURY.

The extent to which alfalfa seed is damaged by the chalcis-fly is not generally apparent, owing to the minuteness of the insect and because its destructive work is accomplished within the growing seeds. The alfalfa-seed grower can only estimate the percentage of his crop destroyed by opening a large number of the seed pods and observing the infested seeds. Even then he can not

estimate with any degree of accuracy without the aid of a good microscope.

Alfalfa seed pods collected in different localities from both early and late crops show that seed crops maturing late in the season suffer a greater loss from this insect than those maturing early. Observations showed that the early emerging adults are crowded to the first seed pods in large numbers, resulting in a heavy infestation. These first pods are, however, nearly always found on the isolated plants growing on fence lines and ditch banks.

In localities where bur clover is abundant the pods of these plants receive the early infestation.

When the alfalfa pods develop in large numbers on the early seed fields there is apparently a decrease in the percentage of in-

FIG. 5.—A severely infested alfalfa seed field which had been abandoned. Infested pods cover the ground, where they offer favorable conditions for the hibernation of the chalcis-fly. (Original.)

fested seed, and from this time on a gradually increased infestation follows until the close of the season.

Seed pods collected in different localities and subjected to examination with a microscope show that the chalcis-fly destroys from 10 to 30 per cent of the seeds in the early crops and from 20 to 70 per cent of the seeds in the late crops. Several samples were examined which showed that 85 per cent of the seed had been destroyed by this insect.

The actual loss per acre depends upon the market value of the seed and upon the yield per acre of the crop. The loss has been observed on different farms to vary from $5 to $60 per acre. There are still many seed-growing districts which have not been visited in connection with this study and where little is known concerning the work of the chalcis-fly.

CONTROL METHODS.

Methods for the practical control of this insect pest are being conducted; and while they are still in an experimental stage, the following pages give fundamental practices which should be carefully carried out by every alfalfa-seed grower to obtain immediate results.

HARVESTING SEVERELY INFESTED CROPS.

An alfalfa field is frequently found with such a severe infestation by chalcis-flies that the grower considers it of insufficient value to be harvested and simply drives in a herd of cows to pasture the crop. (See fig. 5.) With regard to the control of the chalcis-fly for the protection of future seed production, this is a costly mistake.

FIG. 6.—This ditch bank, 3½ rods wide, with its neglected alfalfa, was a place of breeding and hibernation for the chalcis fly—a source sufficient for the infestation of surrounding fields. (Original.)

Observations show that many of the pods burst open, while others are trampled to the ground. Here great numbers of infested seeds offer favorable conditions for the hibernation of the chalcis-fly larvæ. These, as mature flies, will infest the seed crop the following spring. Under such circumstances the crop should be mowed, removed from the field, and stacked. It may then be used as rough fodder; and if the remaining straw is burned in early spring, the hibernating larvæ will be destroyed.

CLEANING FENCE LINES AND DITCH BANKS.

The following facts emphasize the importance of cutting the alfalfa along ditch banks (figs. 6, 7) and fence lines, as well as in the fields.

1. The earliest seed pods are found to develop on the isolated and vigorous growing plants found in such places.

2. The earliest pods have an especially large percentage of the seeds infested with chalcis-fly larvæ.

3. The chalcis-fly larvæ are able to pass completely through the first generation in the earliest pods before the regular seed fields are sufficiently advanced for oviposition.

This cutting should be done with the harvesting of each hay crop, before the seed crop is grown.

It is sometimes necessary to have two or more irrigation ditches running parallel, making it impracticable to cut the alfalfa between them. In such cases it is economy to fence the ditches and use this

FIG. 7.—The rank growth of dry alfalfa shown on this ditch bank was loaded with infested seed pods in which a multitude of chalcis-fly larvæ were hibernating. (Original.)

land as a small summer pasture, thus preventing the development of alfalfa seed pods and the chalcis-flies.

WINTER CULTIVATION.

In the process of harvesting the seed crop many pods containing infested seeds fall to the ground. Here they remain until the following spring when the hibernating insects emerge. A thorough cultivation with an alfalfa cultivator, at some time late in the fall or in early winter, will sufficiently cover such pods and will prevent the emergence of most of the adults when the warm spring weather arrives.

DESTROYING THE SCREENINGS.

After the alfalfa is thrashed the great mass of screenings which is left (see fig. 8) frequently contains large numbers of seeds infested with hibernating larvæ. If the chaff, together with the screenings, is placed in a compost pile for three or four months, so that it will

become heated and decay, most of the insect life will be destroyed. Unless it is possible to treat the screenings in this manner they should be burned before the growing season opens in the spring.

BURNING FENCE LINES AND CHECK RIDGES.

Many of the alfalfa seed pods along check ridges and fence lines may be destroyed by burning off the weeds and alfalfa, as is shown in figure 9. This should be done either in the fall or early spring.

PLANTING CLEAN SEEDS.

In purchasing alfalfa seed, farmers should insist upon having seed which has been well cleaned after thrashing and should never plant

FIG. 8.—An alfalfa straw stack, showing the ground covered with screenings in which many chalcis-fly larvæ are hibernating. (Original.)

the uncleaned product in new fields. In many localities much of the seed is sold both by farmers and by local dealers without first having been cleaned. The product of such seed when harvested from the late crops frequently contains a 10 to 15 per cent infestation of hibernating chalcis-fly larvæ. The planting of this uncleaned seed frequently gives the chalcis-fly a start in the new field, as well as resulting in a poor stand.

CUTTING THE SEED CROP.

It is not an uncommon practice for the farmer to allow the seed crop to remain on the fields an excessive period in order that more of the green pods may develop. In such fields on the same plant are found ripe pods bursting open, as well as fully developed, half-grown, and newly forming pods.

Observations show that many of the chalcis-flies infesting the earlier or first pods have had sufficient time to complete their life develop-

ment, emerge from the seeds, and deposit their eggs into the green pods growing on the same plant upon which they themselves were fostered.

In view of this the seed crop should be so handled that the setting of pods will be as uniform as possible, and the crop should then be harvested as soon as the larger number of the pods are ripe.

STACKING THE SEED CROP.

It has been demonstrated that great numbers of chalcis-flies emerge from the seed pods at about the time the pods ripen, and continue to emerge indefinitely. In midsummer most of them, however, emerge

FIG. 9.—An alfalfa seed field with check ridges and fence lines burned over to destroy the hibernating larvæ of the chalcis-fly. (Original.)

within three or four weeks after the crop is harvested. Where later seed crops are grown, it is therefore advisable to stack the early crops as soon as possible, thus preventing the free emergence offered by leaving the crop in shocks on the field.

DESTROYING BUR CLOVER.

In some localities bur clover grows abundantly and matures its seed pods in early spring. The chalcis-flies thus have already completed the development of an entire generation in the seeds of these plants before the alfalfa seed pods have developed in the fields. Under such conditions it would be well to destroy the bur clover pods by burning the fence lines in the spring. This can frequently be done after the plants mature and before the alfalfa seed crop comes on.

CLEANING THE SEEDS.

Some of the alfalfa seed-growing districts have organizations among the seed growers with officers having complete charge of cleaning and marketing the seeds for the growers. The product handled

through these organizations is, for the most part, well cleaned, so that nearly all of the infested seeds are removed before marketing. (See fig. 10.) When done on a large scale the cost of cleaning the seed is about 10 cents per 100 pounds. In addition to removing the infested alfalfa seeds, this process removes the weed seeds, and the product will then command the highest market prices. Where it is

FIG. 10.—An interior view of an alfalfa seed-cleaning plant, where the infested seeds, together with weed seeds, are removed before the product is sold for planting. (Original).

necessary to do the cleaning on the farm, good results may be secured by using the proper sieves in a small fanning mill.

NECESSITY OF ORGANIZED EFFORTS.

The habits of this insect, together with the general practices of alfalfa-seed growers, make it necessary for the growers of each district to cooperate in an effort to control this destructive seed pest. While it is important that each farmer do all in his power to reduce the abundance of this insect on his own farm, the efforts of an individual are greatly hampered by the negligent habits of a neighbor. The rapid distribution from breeding centers of the chalcis-flies and the short minimum period required for the development of the adults render organized action necessary.

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U.S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

637

Contribution from the Bureau of Entomology, L. O. Howard, Chief,
January 25, 1915.

THE GRASSHOPPER PROBLEM AND ALFALFA CULTURE.

By F. M. Webster,
In Charge of Cereal and Forage Insect Investigations.

SPECIES RESPONSIBLE FOR DEPREDATIONS.

While specimens of the species of grasshoppers actually engaged in devastating alfalfa fields have not always accompanied complaints of their ravages, it is nevertheless possible, taking the data secured by Government and State officials in connection with information from correspondents, accompanied by specimens of the insects actually committing these depredations, to fix the responsibility—largely at least—upon three species. One of these is known as the differential grasshopper (*Melanoplus differentialis* Thos., fig. 1), another as the two-striped grasshopper (*Melanoplus bivittatus* Say., fig. 2), and the third, *Melanoplus atlanis* Riley; the last being more or less migratory.

Other species of grasshoppers have probably at times been more or less involved, as it is rarely that material submitted with a complaint of damages does not include more than one species; on the other hand, species ravaging other crops on the same farm or ranch are often submitted under the supposition that they are like those seen at work in alfalfa. A notable case in point is that of the yellow-winged or pellucid grasshopper (*Camnula pellucida* Scudd.), which, while very destructive to grain and grass crops, is said to work but little injury to alfalfa. However, as all grasshoppers likely to become involved in this or similar depredations have much the same habits and all are probably susceptible to the same treatment, the question of species is not one to interest the farmer particularly, beyond the matter of his ability to determine for himself which one is the worst pest and to apply his measures of suppression more especially with reference thereto.

APPLICABILITY OF MEASURES HEREIN DESCRIBED TO CLOVER CROPS.

While this bulletin is primarily for the benefit of the alfalfa grower, the measures of suppression recommended may be applied in the

Note.—This bulletin describes the species of grasshoppers that work special injury to the alfalfa fields and suggests methods for their destruction. It will be of interest wherever alfalfa is threatened by an attack from these insects.

clover fields of the eastern section of the country with equally good results. Indeed, the three species here discussed are at times destructively abundant in the red-clover fields of the East and Middle West, and the writer has there used the "hopperdozer" to advantage.

EARLY DEPREDATIONS.

With the rapid increase in the culture of alfalfa throughout the country there has come the problem of protecting this crop from attacks of several species of grasshoppers, or locusts. The reason for this state of affairs is not at all obscure, as in order to breed freely and in destructive numbers these grasshoppers require two conditions: First, an undisturbed soil for the protection of their eggs after these have been deposited; and, second, an early food supply for the young in spring. No other crop comes so near supplying these conditions to an ideal degree as does alfalfa.

FIG. 1.—Differential grasshopper (*Melanoplus differentialis*). Natural size. (After Riley.)

Thus it is that the farmer, especially in the West, has from the beginning of alfalfa culture been sorely beset by these pests, whose destructive hordes might even now be said to follow closely in the footprints of the reclamation engineer.

SERIOUSNESS OF INJURIES.

Hardly a season passes during which more or less serious outbreaks [illegible]ported in different localities, and the aid of the Bureau of [illegible]gy is frequently invoked in destroying these grasshoppers [illegible]rise lessening their ravages. Thus, during the year 1913, [illegible] widespread injuries occurred in New Mexico, Kansas, Oklahoma, New Hampshire, and Vermont, with lesser outbreaks in Arizona, Texas, Mississippi, Wisconsin, Michigan, and Wyoming. It is in no wise likely that these numbers indicate more than a minor portion of the destructive outbreaks of these pests that actually occurred over this territory, and the seriousness of some of these outbreaks is indicated by the fact that as many as 12 complaints were received from a single locality. In fact, the probabilities are that, as the area of cultivation of alfalfa increases, the amount of injury inflicted by these insects will greatly increase in future unless measures are taken to control them.

DESCRIPTIONS OF THE TWO PRINCIPAL ALFALFA-AFFECTING SPECIES.

The differential grasshopper (fig. 1) is about 1½ inches long, its wings expand about 2½ inches, and it is of a general bright yellowish-green color. There is, however, a nearly black melanic form that does not seem to differ otherwise from the normal. The head and thorax are olive brown, and the front wings are of very much the same color, without other markings but with a brownish shade at the base; the hind wings are tinged with green; the hind thighs are bright yellow, especially below, with four black marks; the hind shanks are yellow, with black spines and a ring of the same color near the base.

FIG. 2.—Two-striped grasshopper (*Melanoplus bivittatus*). Natural size. (After Riley.)

The two-striped grasshopper (fig. 2) varies in color from a dull green to a dull brown, with a distinct yellow stripe extending on each side from the upper part of the eye to the end of the wing. The male is about 1¼ inches long and the female about one-fourth of an inch longer. This grasshopper may be so easily recognized from the accompanying figure that further description is unnecessary.

The young are very much like those of the Rocky Mountain grasshopper, or locust, shown in figure 3.

FIG. 3.—Rocky Mountain grasshopper or locust (*Melanoplus spretus*): *a*, *a*, Newly hatched larvæ; *b*, full-grown larva; *c*, pupa. Natural size. (After Riley.)

DISTRIBUTION OF THE TWO SPECIES.

Although both these grasshoppers seem to be generally distributed over the country, the differential grasshopper rarely becomes destructively abundant east of the Mississippi River. It is very decidedly so, and with great frequency, however, to the west of the Mississippi, while, though extending from Maine to California, the two-striped grasshopper is sometimes disastrously abundant, locally at least, as far east as Ohio. In the red-clover-growing sections of the country the two-striped species is probably very much the more destructive of the two, though even as far east as Indiana the differential grasshopper does considerable injury to fruit trees by gnawing the bark from the twigs.

LIFE HISTORIES AND HABITS.

The eggs are deposited in the ground in masses, inclosed in more or less kidney-shaped pods, in late summer and fall, after the manner shown in figure 4, which illustrates the oviposition of the Rocky Mountain grasshopper or locust. The females seem to prefer a moderately compact, rather damp but not wet soil which is rarely disturbed by the plow or other cultivating implement. It will thus be seen that the alfalfa fields throughout the irrigated sections constitute an ideal breeding ground. Winter is passed in the egg state, the young hatching in spring and reaching maturity in summer, and there is but one generation annually. Neither of the two species is migratory. Their flight is rather clumsy, and they do not remain long on the wing before alighting.

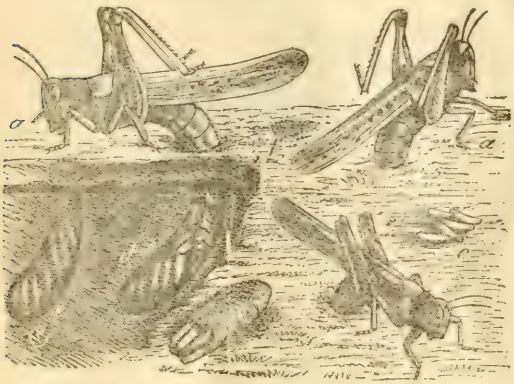

FIG. 4.—Rocky Mountain grasshopper or locust (*Melanoplus spretus*): *a*, *a*, *a*, Female in different positions, ovipositing; *b*, egg-pod extracted from ground, with the end broken open; [illegible]ose on the ground; *d* and *e* show the earth [illegible] to illustrate an egg mass already in place [illegible]ed; *f* shows where such a mass has been [illegible] Riley.)

NATURAL ENEMIES.

Upward of 100 species of birds are known to feed to a greater or less extent upon grasshoppers, but probably the most useful in this direction are quails, prairie chickens, the sparrow hawk and Swainson hawk, the loggerhead shrike, all cuckoos, the cowbird, all blackbirds and meadowlarks, the catbird, and the red-headed woodpecker. That domestic fowls are especially fond of these insects goes without saying. Skunks are very fond of grasshoppers, and are esteemed by the Bureau of Biological Survey as the most useful of mammals; they therefore deserve protection rather than destruction by the farmer. Toads and probably some of the snakes add these insects to their bill of fare.

Of the insect enemies, the grasshopper mite is often found infesting grasshoppers in great numbers. It collects under the base of the wings, sometimes causing them to stand out from the body. While these mites probably destroy many grasshoppers, it is possible that their value to the farmer has been overestimated. There are several species of parasitic flies that frequently destroy immense numbers of these grasshoppers. Of these *Sarcophaga kellyi* Ald., *S. cimbicis* Towns.,

S. hunteri Hough, and *S. georgina* Wied. (fig. 5) sometimes sweep these locusts off in myriads. These flies deposit minute, elongate maggots on the surface of the bodies of the grasshoppers. The young maggots make their way directly into the body of their host, and as they grow and develop there they feed upon the living insect. When full grown the maggots go into the ground and within a brown case transform to flies. Quite recently Mr. E. O. G. Kelly, of the Bureau of Entomology, has discovered a species of Sarcophaga attacking grasshoppers in great numbers in the State of Kansas. This species deposits the tiny maggots upon the outstretched wings of the grasshopper when in flight, whence the maggots make their way into the soft integuments of the body. Mr. H. E. Smith observed the same species likewise depositing its larvæ on its victims while the latter were quietly clinging to vegetation. This species was found to be new to science, and has been described under the name of *Sarcophaga kellyi* by Dr. J. M. Aldrich.

FIG. 5.—*Sarcophaga georgina*, a parasitic fly that destroys grasshoppers. Much enlarged. (Author's illustration.)

While all of these natural enemies do much to hold the pests in check, there are two or three vegetable parasites that also kill off myriads of them, the dead bodies of the grasshoppers destroyed thereby often being conspicuous objects as they cling to the weeds and grass where death overtook them (see fig. 6). One of these fungous parasites is the same as that attacking the chinch bug, and is known to science as *Sporotrichum globuliferum*. A group of grasshoppers that have been killed by this fungus is shown in figure 7.

While it will be seen that there is no lack of natural enemies of these grasshoppers, and while all of them are of benefit to the farmer, they do not and never will afford absolute protection from the ravages of these pests in the alfalfa fields. The reason for this is plain. By growing a single plant over large areas the farmer produces an unnatural condition and offers unnatural advantages for the development of the enemies of this plant, the grasshoppers. It is really the number of plants that invites insect attack. So, also, it is the great number of grasshoppers congregated together in masses that invites attack from natural enemies, and it is only when this condi-

tion is present that these natural enemies become sufficiently abundant to offer the farmer prompt and effective relief. In other words, the natural enemies, however much restraining force they may present, are always too far behind wholly to prevent occasional outbreaks of these grasshoppers. The farmer, having undertaken the cultivation of alfalfa in large areas under conditions preeminently favorable for

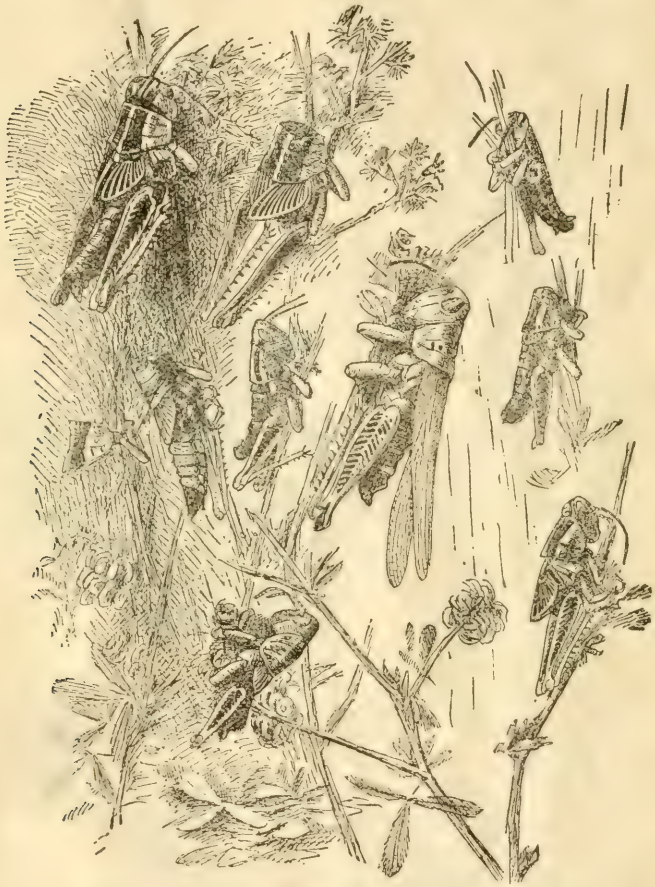

FIG. 6.—A view of grasshoppers dead and dying from fungous disease. Natural size. (From Howard.)

the development of grasshoppers, must now throw some restraining element into the other side of the scales in order to preserve the balance. It thus comes about that artificial repressive measures must be put into play in order to counteract, as it were, the effect on nature of an overabundance of alfalfa plants—a vastly greater number than would be produced under natural conditions. And this brings us to a consideration of preventive and repressive measures.

PREVENTIVE AND REMEDIAL MEASURES.

Preventive measures, as here restricted, apply to a period antedating the hatching of the young; while remedial measures are such as deal with the insects after hatching and with methods of destroying them.

While many modes of procedure have been advocated, tending to ward off impending attacks, and perhaps even a greater number of devices constructed and mixtures compounded for the destruction of grasshoppers, we will here consider only such as are readily and cheaply obtainable by the farmer and ranchman and those most practical in application.

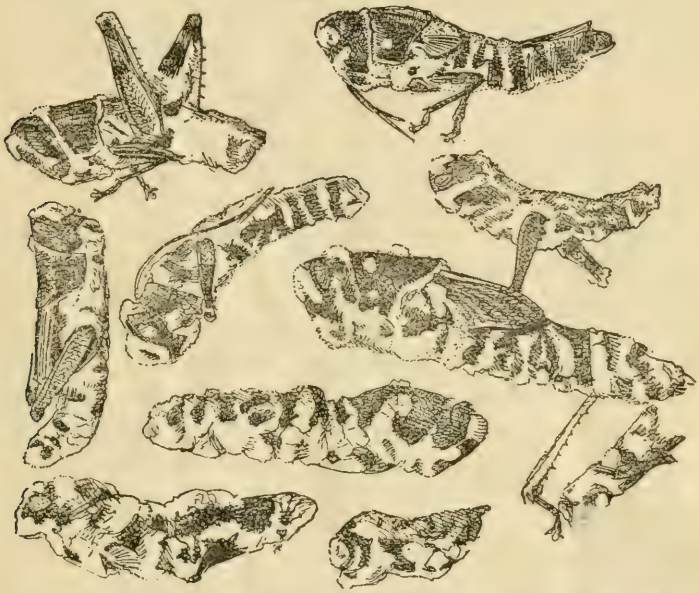

FIG. 7.—Grasshoppers killed by fungus, *Sporotrichum globuliferum*.

DESTROYING THE EGGS.

Destroying the eggs of the grasshoppers seems to be the only preventive measure that promises to be worth while attempting, except, perhaps, the destruction of the young as they are hatching. Destruction of the eggs may be accomplished by either plowing, harrowing, disking, or cultivating, in the fall or winter, all roadsides, ditch banks, margins of cultivated fields, uncultivated fields, and grassy margins along fences. In short, all waste lands that it is possible to reach in this manner should receive attention, unless it is known that no eggs were deposited there.

The soil need not be stirred deeply, 2 inches being a sufficient depth to accomplish the desired effect; and circumstances will probably dictate the kind of tool or tools that a farmer ought to

use and where to use them. There is no doubt whatever that if this measure were put into operation at the proper time, in whatever manner is most practicable, disastrous outbreaks the following spring would be forestalled and prevented. Except in cases of isolated farms or ranches, there should by all means be concerted action in this movement.

Where fields can be quickly inundated and the water promptly run off, as is frequently done in rice fields, the young grasshoppers may be killed by flooding the field for a day or two just as the eggs are hatching. If close watch is kept to determine just when the young grasshoppers are hatching, and prompt action taken at this time, much good can be accomplished; but as soon as the young begin to move about flooding will avail but little, as the grasshoppers will climb to the upper part of vegetation beyond the reach of the water.

DESTROYING THE INSECTS.

Those measures which should be resorted to when the grasshoppers, having hatched from the egg, are threatening alfalfa fields from within or without, or both, will now be discussed.

The hopperdozer.—On level or comparatively level land the hopperdozer can be used to good advantage in collecting grasshoppers of all ages—from the youngest to the adults. There are many modifications in the construction of these implements, but the form here described and figured has been made for the writer, and he has employed it in the fields and knows from experience that its use is both practicable and efficient. It is constructed of sheet iron, preferably galvanized, of reasonable thickness to insure strength, and, except for the end pieces, made of a single sheet 10 or 12 feet long and 26 inches in width. The front is formed by turning up one edge a couple of inches, and the back may be turned up a foot, thus making a shallow pan 1 foot wide, with the back the same height and with a front 2 inches high. Ends are riveted in and soldered, as shown in figure 8. Runners of old wagon tire are placed at each end (*a*, *b*), and another in the center (*c*) is turned over in the front and back to strengthen the pan at these points. These runners are riveted to the pan, as shown, and should extend both backward and forward in order to overcome to some extent the inequalities of the ground and cause the hopperdozer to run more smoothly. By soldering it about the heads of the rivets the pan will be made water-tight. The pan is filled with water, on which is poured enough kerosene to cover it with a film, a horse is hitched to the end runners, and the outfit is then ready for use. As the hopperdozer is drawn over the ground the locusts will either jump into the kerosene and water direct or against the back and drop into it and there be killed. By using longer, wider, and heavier sheet iron a larger and stronger pan

can be made and this further strengthened by additional runners; a horse can then be hitched to each end, or the pan may be mounted on low wheels. The whole thing is easily constructed, inexpensive, and once made may be put into service year after year as needed. The only place where its use will prove more or less impracticable will be on hilly or rocky lands or on that not yet cleared of stumps.

Poisoned baits.—In the use of poisoned baits we have another inexpensive, practical way of dealing with these grasshoppers even when, as is frequently the case, they breed in the alfalfa fields, and the protection, whatever it may be, must be applied there. What has come to be known as the "Criddle mixture" is giving most satisfactory results on the ranches of both the United States and Canada. The mixture is composed of half a barrel of fresh horse droppings in which is mixed 1 pound each of salt and Paris Green. If the horse droppings are not fresh, the salt is dissolved in water and mixed

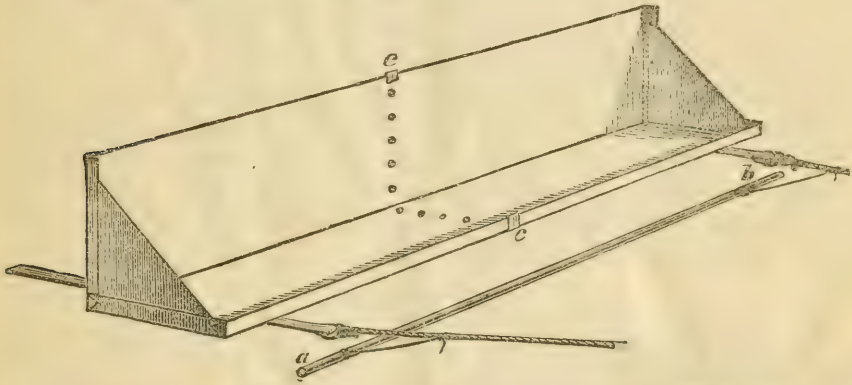

FIG. 8.—"Hopperdozer." A simple coal-oil pan, to be drawn by 1

with the manure and poison. When this mixture is scattered freely about where the grasshoppers are abundant, they seem to be attracted to it, for they devour it readily and are poisoned thereby. Dr. James Fletcher, late entomologist for the Dominion of Canada, cited an instance where this mixture had been scattered freely around the edges of a field, and stated that this particular field stood out as a green patch in a brown plain, as it was situated in the midst of fields where nothing had been done to destroy the grasshoppers.

Another effective bait is made by mixing wheat bran, 25 pounds; Paris green, 1 pound; cheap molasses or sirup, 2 quarts; oranges or lemons, 3 fruits. Thoroughly mix together the bran and Paris green. An ordinary washtub will answer for this purpose. Into a separate receptacle containing the molasses or sirup, squeeze the juices of the fruit; then chop up finely the skin and pulp of the fruit and add this also to the molasses mixture; then dilute with 2 gallons of water. Mix the two together and add enough more water to bring the

whole to a stiff dough. This amount of poison bait is sufficient to treat from 5 to 10 acres when properly applied. It should be borne in mind, however, that the fruit is the essential element of this bait, and if not employed 75 per cent of the efficiency of the bait is lost.

This poison bait should be applied to the area to be treated early in the morning, before sunrise. To obtain the best results the bait must be sown broadcast in strips 1 rod apart over the area to be treated. Broadcasting obviates the possibility of horses, cattle, sheep, poultry, or birds being able to obtain a sufficient amount of poison in the field to kill or injure them. Under no circumstances should the bait be scattered over treated areas in piles or bunches, for fear that birds or live stock might, under such circumstances, eat an injurious or fatal amount of the poison.

To illustrate the degree of safety with which the poison bait may be used when properly sown broadcast, the following may be of interest: In the summer of 1914, on the farm of Mr. C. I. Hood, of Chelsea, Vt., the pasture of several hundred acres was very badly infested with *Melanoplus atlanis* Riley. In this pasture there were continually grazing more than a hundred of very highly prized pure-bred Jersey heifers. From 10 to 15 acres of this pasture were treated with 25 pounds of the poison bran each morning for a week, and though the heifers continually grazed over the treated areas, not a single instance of poisoning occurred.

COOPERATION.

Cooperation between farmers or ranchmen is of the utmost importance, whether the hopperdozer or poisoned baits be used. On some of the more extensive ranches the owners can protect themselves by reason of the great extent of territory that is under the control of a single individual, but among smaller holdings cooperation is very essential.

FORESTALLING OUTBREAKS.

Forestalling of outbreaks would be spoken of by the ranchman as "watching out for trouble." By this is meant the careful watching of the fields for the appearance of the grasshoppers. When these are found to be present, do not wait to see what they are going to do, but prevent their doing any thing by putting into practice, before any damage has been done and while the grasshoppers are very young, whatever measures are to be used. It usually requires several days to poison the grasshoppers, and large areas can not be traversed with the hopperdozers in a day. Therefore if measures are to be successful they must not be delayed.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 640 MARCH 17, 1915.

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE HESSIAN FLY.[1]

By F. M. WEBSTER,

In Charge of Cereal and Forage Insect Investigations.

INTRODUCTION.

Probably no other insect causes more damage to the wheat crop of the United States than the Hessian fly, though the chinch bug is doubtless a close second. During years when it is excessively abundant, hundreds of thousands of acres of wheat may be either

FIG. 1.—The Hessian fly (*Mayetiola destructor*): Adult female. Much enlarged. (Author's illustration.)

totally destroyed or so badly injured as to reduce the yield 50 to 75 per cent, and the monetary losses expressed in dollars would run far up into the millions. This insect has long been known to ravage

[1] *Mayetiola destructor* Say; order Diptera, family Itonidæ.

NOTE.—This bulletin is of interest in all the grain-growing sections of the United States, but especially in the regions shaded in the distribution map (fig. 8, p. 7). It is a revision of Circular No. 70 of the Bureau of Entomology.

our wheat fields, yet farmers are, in many cases, still at a loss regarding the best methods of warding off its devastation.

EARLY HISTORY IN AMERICA.

The common name, "Hessian fly," was long ago bestowed upon this insect by Americans, because of its having committed some depredations on Long Island, New York, in 1779, in the vicinity of Lord Howe's old encampment of three years before. The Hessian mercenaries who constituted a part of this army were much despised, both at home and in America, and, on the supposition that these soldiers had brought the pest with them from their native country in the straw used for their bedding while en route, it was given the obnoxious name of "Hessian fly." Whether or not this theory of its introduction was well founded can never be either substantiated or disproven, and all that can now be said is, that the pest was imported, probably from some trans-Atlantic country and some time during the latter half of the eighteenth century. As a matter of interest, it may be stated that, in some quarters, the more ignorant Tory element of those days claimed that General Washington was responsible for this pest. It was not technically described until 1817.

FIG. 2.—The Hessian fly: Adult male. Much enlarged. (Original.)

DESCRIPTION OF THE INSECT.

The fly itself (fig. 1, female; fig. 2, male) is very small, being only about one-tenth of an inch long, the body of an obscure dark color, and the form much like that of a very small mosquito. The abdomen of the female (fig. 1) is red, or yellowish when first hatched from

the "flaxseed," the color varying with age, the posterior segments terminating in a compressed cylindrical, very minutely hairy ovipositor, capable of great extension. The male (fig. 2) is smaller, more slender, and in color generally darker than the female, the abdomen terminating in a somewhat intricate organ composed of a set each of outer and inner claspers.

The egg (fig. 3) is very minute, being only about one-fiftieth of an inch in length, cylindrical, roundingly pointed at the ends, glossy translucent, and slightly reddish, this color deepening with development.

The larva or maggot (fig. 4), when newly hatched, is a little smaller than the egg, with a slightly reddish tinge; later, as it increases in size, it is at first white and afterwards greenish white, clouded internally by flaky white.

After the larva has reached its full growth and the skin has hardened and turned brown, forming a covering known as a puparium, the insect is known as the flaxseed (fig. 6). There is at this time a minute, brown, forked process on the underside of the anterior end of the larva, known as the "breastbone" (fig. 5), the use of which is not fully understood. It is not present, however, until the larva enters the flaxseed state. Within this "flaxseed" it transforms first to a pupa (fig. 7), and from this to an adult fly. The term "flaxseed" is applied partly because of its brown color and partly because it is more or less flattened, thus giving it somewhat the appearance of a flaxseed.

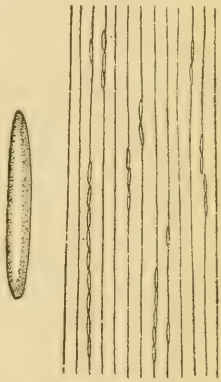

FIG. 3.—Egg of Hessian fly, greatly enlarged; section of leaf of wheat, at right, showing eggs as usually deposited, less enlarged. (Author's illustration.)

WHERE TO FIND THE DIFFERENT STAGES.

From the foregoing descriptions it will be observed that during the life of this insect it is found in four very different forms, so entirely unlike in appearance as to confuse the average farmer.

The eggs (fig. 3), which may be easily seen by one with fairly good eyesight, are generally placed in the grooves of the upper surface of the leaves, though they are occasionally found on the underside of the leaf. When the young wheat plant is just pushing through the ground, the egg is sometimes placed on the outside, because no leaves are available.

The young larva is slightly smaller than the egg, and as soon as it is hatched it makes its way down the leaf and behind the sheath. In case of young wheat it descends to just above the root, but after the plants have begun to joint it can go no farther than the base of the sheath belonging to that particular leaf, which is always at the

joint. Where excessively abundant, the larvæ will frequently be found on the lower stem ranged one behind the other, the anterior end of one pushed slightly under the posterior end of the one in advance. Very often this position is maintained throughout the entire development of the larva (figs. 4 and 5), and the flaxseeds (figs. 6 and 10) still retain the same relative position.

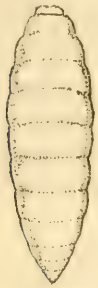

FIG. 4.—The Hessian fly: Larva before "flaxseed" is formed. Much enlarged. (Author's illustration.)

The fall generation of larvæ and the overwintering flaxseeds are to be found just above the roots (fig. 10), except in cases where the young plant has become disintegrated and separated at the point of attack in the fall or the plants have been heaved out by the action of freezing and thawing, in which case they may be scattered about on the surface of the ground.

The young make their way down the plant head foremost, and so remain until before pupating, when they reverse their position in the flaxseed and are then situated head upward, and thus pass into the pupal stage. Before the fly issues, however, if the flaxseed is not situated conveniently for its escape, the pupa will push itself, if possible, to such a point, and frequently empty pupa skins may be observed protruding from under the sheaths of the leaves.

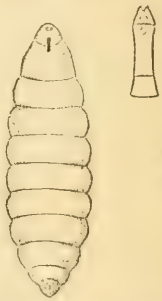

FIG. 5.—The Hessian fly: Larva taken from "flaxseed." Much enlarged, with "breastbone" still more enlarged at right. (Author's illustration.)

The fly itself is not easily observed until one becomes familiar with its appearance, and this will account for the great variety of insects that are continually mistaken by farmers for the Hessian fly. Much of this difficulty may be obviated if farmers will look for an insect like that shown in figure 1, but very minute and somewhat resembling a very small mosquito. During warm days, in the egg-laying season, the flies may be observed flying about in the young wheat, alighting upon the leaves. In cooler days, or in early morning while a heavy dew is on, they will be down among the leaves, or even on the ground.

LIFE HISTORY.

At present all indications point to the probability that the Hessian fly has two generations, at least during favorable seasons, over its entire area of distribution in the United States.

In the South the two generations are the most widely separated, while in the North, in the regions of spring-wheat growing, one seems to follow the other in quick succession.

LIFE HISTORY IN REGIONS OF FALL-WHEAT GROWING.

Throughout the fall-wheat-growing sections the fly passes the winter in the young wheat, mostly in the flaxseed stage, but also to some extent as from two-thirds to full-grown larvæ. It is difficult to estimate the number of these larvæ that will winter over and remain alive until spring, owing to the fact that it is impossible to determine whether they are alive or dead until they begin to decay. But where we have attempted to rear them, even though apparently alive, comparatively few adults have been obtained, though, of course, this mortality would probably vary somewhat with the severity of the weather during winter.

FIG. 6.—The Hessian fly: Puparium or "flaxseed." Much enlarged. (Author's illustration.)

In spring (from March in Georgia and South Carolina to May in Michigan) the flies escape from the flaxseeds and deposit their eggs on the wheat, and the young from these develop to flaxseeds before harvest, passing the summer in the stubble. The flies from over-wintering larvæ come on later, and it is quite probable, also, that some of the very earliest deposited eggs may give rise to adults at about this time. Thus, owing to this overlapping, during some seasons and in some localities, there appears just before harvest what has by some been considered a supplementary second generation.

In autumn the time of appearance of adults as between North and South is reversed. In northern Michigan the adults of the fall generation are abroad, under normal meteorological conditions, during the last days of August and first days of September. In Georgia and South Carolina, under the same conditions, it may be the last of November or the first of December before they have all left the stubble. Thus has the species adapted itself to the prolonged southern summer, during which there is little or no food for the larvæ. While there are stragglers, the major part of the generation will appear and disappear within the space of a few days, probably within a week, and the flies, by preference, will deposit their eggs on the younger plants, those of one or two leaves seeming to suit them best. At this time the young larvæ make their way downward nearly or quite to the roots (fig. 10). The normal outcome of this generation is that the individuals reach their development as larvæ, pass into the flaxseed stage, and pass the winter as such on the young wheat plants. But here again the earliest deposited eggs may produce adults before the winter sets in, and the delayed individuals

FIG. 7.—The Hessian fly: Pupa taken from "flaxseed." Greatly enlarged. (After Marlatt.)

occurring at this time may unite, and another supplementary generation, as it has been termed, may be produced. The economic significance of this so-called generation depends much on the weather, as, if winter sets in before the larvæ have sufficiently matured to withstand its rigors, these must necessarily perish, while if the mild autumn weather is greatly prolonged, a greater or less number of them may winter over uninjured.

LIFE HISTORY IN SPRING-WHEAT REGIONS OF THE NORTHWEST.

The statements here made regarding the life history of the Hessian fly in the spring-wheat regions of the Northwest are based largely on the careful investigations carried out by Mr. George I. Reeves, a special field agent of the Bureau of Entomology, during the season of 1905. This single season may have been an exceptional one, in that the spring was backward, the summer wet, and the mild autumn weather continued later than usual. The results must not, therefore, be taken as wholly conclusive.

In North Dakota the insect winters in the flaxseed stage in both stubble and volunteer wheat, chiefly the former. Egg laying begins late in May, and during seasons with plenty of rain the second generation follows the first in quick succession, being reenforced by the continued emergence of flies from stubble of the previous year. Here the summer conditions are different from those in the East and South, and the breeding season extends from about May 20 to October 1, or throughout the entire summer. In other respects the habits of the insect do not seem to differ from what they are in the fall-wheat-growing sections of the country.

DISTRIBUTION.

Outside of America the Hessian fly occurs in North Africa, western Asia, Europe, British Islands, and New Zealand. In the Dominion of Canada Fletcher found it from Prince Edward Island to Indian Head, Saskatchewan. On the Pacific coast it probably occurs from central California to British Columbia; but as no exact investigations have been made there, this statement is to be considered as only approximately correct.

Our previous notions of the distribution of this insect over the country east of the Rocky Mountains will have to be revised. The accompanying map (fig. 8) shows the extent to which this revision becomes necessary.

The dotted area indicates the present distribution of the Hessian fly based on our latest observations and data furnished by Prof. Lawrence Bruner, of Nebraska, and Mr. R. I. Smith, entomologist of the Georgia State crop pest commission. This is believed to be approximately correct. It also seems to show that the insect must

have been first introduced into the Pacific coast region in or with articles of inland commerce, and, unless it be found to infest native grasses, that it did not reach there by natural diffusion, a point that has not before been definitely stated so as to be clearly understood.

Experimental sowings of wheat near Sault Ste. Marie, Mich., during the years 1904 and 1905 do not reveal its presence there, and no attempt has been made to study its occurrence in the spring-wheat-growing sections of Maine. While its absence in some parts of the country between the Platte River, in Nebraska, and the Canadian boundary line might be attributed to a lack of its food plant, this will not hold in southwestern Kansas and Oklahoma, as in those localities it seems to terminate suddenly in the midst of a wheat-growing sec-

FIG. 8.—Map showing distribution of the Hessian fly in the United States in 1914. (Original.)

tion, and where this grain has been cultivated for at least twenty years. Strange as this may at first appear, Dr. C. Hart Merriam, formerly Chief of the Biological Survey of the U. S. Department of Agriculture, informed the writer that he has found several parallel cases in the distribution of some of the smaller mammals.

FOOD PLANTS.

The chief food plant of the Hessian fly is wheat, next to this barley, and lastly rye. In the last plant, however, it does not develop freely, and it does not attack oats at all. Many years ago Lindemann, in Russia, found what he determined as the flaxseeds of the Hessian fly on timothy and *Agropyron repens*. Later Mr. Albert Koebele found flaxseeds closely resembling those of the Hessian fly on Elymus, Agrostis, Bromus, and Agropyron in California. Still later

Mr. W. J. Phillips found similar flaxseeds in Agropyron about Richmond, Ind., May, 1908. During September of the same year Mr. E. O. G. Kelly found the Hessian fly breeding in abundance in *Agropyron smithii* in the vicinity of Wellington, Kans. This appearance of the Hessian fly in this grass during 1908 and 1909 was very marked

FIG. 9.—Healthy young wheat plant. (Author's illustration.)

indeed, owing to the fact that the grass was growing within the Chicago, Rock Island, and Pacific Railway right of way. The dried grass was burned off, so that the fresh growth came up just at the time that the Hessian flies were abroad depositing their eggs. The young grass plants were not only abundant but convenient and the flies

utilized them, placing an enormous number of eggs on the upper surface of the leaves, precisely as is their wont in the case of grains. The larvæ, after making their way down the sheaths and beginning to attack the plants, gave to them precisely the same appearance as infested wheat plants. Under these circumstances the Hessian fly appeared to breed as freely in *Agropyron smithii* as in wheat. On October 25 of the following year Mr. G. I. Reeves found many Hessian fly eggs and larvæ in all stages of development up to the flaxseed on *Agropyron repens*, and probably also on other varieties of this grass, growing up in the wheat fields in the vicinity of Vancouver, Wash. Mr. C. N. Ainslie found the flaxseed stage of the Hessian fly in *Agropyron tenerum* growing in alleys at Elk Point, S. Dak., June 23, 1913. There is therefore no doubt whatever but that the Hessian fly will breed in Agropyron, and perhaps also, in some portions of the country, to a limited extent, in Elymus, Agrostis, and Bromus. Dr. S. A. Forbes a number of years ago failed to induce the fly to breed in either redtop, bluegrass, foxtail, or orchard grass.

EFFECT OF LARVÆ ON THE PLANT.

The effect of the larvæ on a young wheat plant is very marked and becomes observable soon after the young reach the stem under the sheath. Once he has observed it, any farmer can readily detect an infested plant, or a single infested tiller may be as readily detected in a cluster without taking the trouble to remove the plant from the ground.

For the purpose of comparison, illustrations are given of an uninfested young plant (fig. 9) and an infested young plant (fig. 10). An uninfested plant is of a more slender growth, the green color is lighter, with a slight tinge of yellow, the stems are more or less visible, and the central unfolding leaf is present. The whole plant is inclined to droop and the tillers spread out and cover the ground. An infested plant is without stem and the leaves are broader, usually shorter and of a deep bluish-green color, somewhat resembling those of oats. The plant stands more erect, and, in fact, is but a mass of short overgrown leaves that usually kill with the first frost. Figure 10 shows a young tiller starting out from below the part attacked by the fly. If this tiller were to be attacked after it appeared above ground, there would follow the same appearance as in case of the original plant; that is to say, the leaves would become broader and of a darker color. The foregoing statement will apply to a severe attack on fall wheat in spring and on young spring wheat. The only exception in the appearance of infested young plants is in the case of the hard wheats, whose foliage is broader and of a darker color, but the erect position will still enable the observer to detect the infestation. Of course later on

the infested plants change to yellow and then brown, but the darker color and rank growth of leaf always precede this.

In summer, in both spring and fall wheat, the effect of the fly is to cause the straw to break over before harvest. It is then said to be "straw fallen."

FIG. 10.—Young wheat plant infested by the Hessian fly. (Author's illustration.)

IMMUNE OR DISTASTEFUL VARIETIES OF WHEATS.

There is no such thing as "fly-proof wheat." Most wheats will suffer when the plants are young, regardless of variety. In experimental sowings a variety that seems to escape attack one year may suffer the next; and, while the insect may prefer certain varieties over others, this all comes to naught in years of serious ravages or where the sup-

posed distasteful variety is in a condition more satisfactory to the insect at the time of oviposition. It is doubtful, however, if this can be said of the attack of the second brood on the more matured plants, as it is quite noticeable that the ranker-growing varieties with strong, stiff straw are the least affected. Then, too, among fall wheats in the northern part of the country it is quite essential that a wheat plant be able to send out tillers from the old roots of plants killed by the fly (fig. 10), and that these tillers prove hardy enough to withstand the winter. Therefore, in selecting varieties of wheat with a view to evading Hessian-fly attack, the farmer will do well to ignore statements on this point from those who have seed to sell and select from the varieties known to do well in his locality such as are of strong, vigorous growth, hardy, and with a stiff straw.

For some reason the durum wheats do not seem to attract the fly, at least not the second brood. In going over fields of this kind of wheat in sections where other spring wheats were suffering from attack by this pest, it was rarely found on a stem of durum wheat, while any straws of other varieties growing from seed that had become intermixed were almost invariably infested. Whether this will hold good in case of the young plants it is as yet impossible to say, because of the difficulty of telling to what varieties the young plants belong. Infested plants have been found in fields of young durum wheat in some considerable numbers; but these plants may have been of other varieties, as the fields had been used for other varieties the year before, and besides the seed itself may have been impure.

METEOROLOGICAL EFFECTS.

All who have carefully studied the Hessian fly under various field conditions during a series of years have noted that weather conditions have an important influence on the insect. Especially is this true in its economic relations to the grains it attacks; hence in the application of preventive measures these weather conditions become of vital importance.

Many farmers place much stress on the effect of cold weather or even of frosts in terminating the flies' work in the fall, and it is for this reason that many try to delay wheat sowing until after there has been a sharp frost. The facts are that the females will be abroad and ovipositing in freezing weather, and Mr. W. J. Phillips has found by experimentation that the eggs will remain in a temperature of 36° F. for seventy-two hours with no other effect than to delay their hatching that much longer. This is about the temperature at which frosts would occur. Indeed, the writer has observed eggs hatching during the day in the fields when there were frosts nearly every night. Whether or not the larvæ from these would get sufficiently advanced

to pass the winter would, of course, depend upon later weather conditions. In the North these much-belated larvæ are killed off by cold weather.

The immunity of the late-sown wheat from attack by the fly is not due to frost, but to the fact that by the time severe frosts usually occur most of the flies have appeared and gone.

The most marked influence of climatic conditions on this insect is seen in the effect of heat and drought, and especially of the two combined. In the South it is the long summer that so widely separates the two generations. Drought has a similar effect on the development of the insect as it has on the germination of the seed which produces its food; thus, dry weather in the late summer and fall tends to keep the insect in the flaxseed stage—a fact of special importance in the North where it is imperative to get the wheat sown early enough to enable the plants to stand the winter. Under exceptional conditions, such as in a dry room, flaxseeds may be kept for a year, or even two, but when moistened the flies will soon emerge. So in the fields they will, during a drought, remain in the flaxseed state for a considerable time after they would appear under normal conditions, and only appear soon after rains have moistened the soil.

The first publication [1] dealing with the generally uniform retardation of development of the fall generation from the north southward was based on work done by the author in Indiana during the years 1886 to 1890, with the aid of experimental plats sown throughout the entire length of the State.

Studies of the Hessian fly in Indiana, which were begun by the author in 1884, very soon indicated that information regarding the development of this insect based on information secured in the northern part of the State would not apply at all in the extreme southern section. So far as known to the writer, this publication is the first on record relating to this particular feature of the development of the pest. Later the same investigation was continued in Ohio.[2] The results of this work showed very clearly that the uniformity of development of the fall generation, which is the one most to be feared by the farmer, was practically the same in Ohio as in Indiana. Even at that time there was an indication of what might be termed a variation from the normal condition in southern Michigan.

Since 1904 similar wheat-sowing experiments have been conducted from northern Michigan and northern New York to central Georgia and across the State of Kansas. As a result of the sowings in Michigan it was found that owing to some influence, probably that of the

[1] Webster, F. M. Report on Some of the Insects Affecting Cereal Crops. The Hessian Fly. *In* U. S. Dept. Agr., Div. Ent., Bul. 23 (old series), pp. 63–79, 1891.

[2] Bulletin No. 7, Vol. IV, of the Ohio Agricultural Experiment Station, published in 1891; Bulletin No. 107 of the same institution, published in 1889; and Bulletin No. 119, also of the same institution, published in June, 1900.

Great Lakes, the farmers of the southern half of southern Michigan could not sow their wheat with safety earlier than the farmers of northern Ohio, say 50 miles to the southward. It is to be pointed out that while east of the Alleghenies the Hessian fly extends from Canada southward to central Georgia, west of the Mississippi River it extends from Canada southward only to northeastern Oklahoma. (See map, fig. 8.) Over the area east of the Mississippi River climatic conditions, due seemingly to latitude, have had the effect of retarding the development of the adult flies in the wheat stubble and their consequent appearance preparatory to egg laying in the fall for a period covering considerably over one month as between southern Michigan and southern Georgia. As a matter of fact, humidity, or the lack of it, seems to be a vastly more important element in influencing the distribution and development of the Hessian fly than either altitude or latitude. In proof of this, during seasons when the wheat crop of Sumner County, southern Kansas, was in many cases totally destroyed by the Hessian fly, at Enid, Okla., approximately 40 miles away to the southward, it was only by the most diligent search that occasional individuals could be found in the wheat fields. The country between these localities is almost exclusively devoted to wheat, so that there was no lack of food plants, and the topography of the country is very much the same, the elevation of Enid being almost exactly that of Wellington. Not only did this condition obtain in the year 1907, but it was practically determined three years earlier by Mr. George I. Reeves, who made a survey of the distribution of the Hessian fly in that part of the country in the fall of 1904. The conditions up to the present remain unchanged. Furthermore, as observed by Mr. E. O. G. Kelly, with the Hessian fly common at Kinsley, Kans., altitude 2,164 feet, and located 36 miles east of Dodge City, and destructively abundant at Great Bend, elevation 1,843 feet, 82 miles northeast of Dodge City, and at Larned, elevation 1,995 feet, 60 miles from Dodge City and located between Great Bend and Kinsley, careful search at various times by several assistants of the Bureau of Entomology have utterly failed to reveal a single individual Hessian fly in the wheat fields at Dodge City, elevation 2,480 feet, with wheat growing continuously between this point and Great Bend, Larned, and Kinsley.

In the spring of 1913 wheat plants carrying approximately 1,200 flaxseeds of the Hessian fly were transplanted by Mr. Kelly from Sedgewick, Kans., to Dodge City, placed in a rearing cage with mesh sufficiently fine to retain the adult insects, and put in the fields April 9, 1913, under as exact field conditions as it was possible to obtain. This cage was allowed to remain in place until May 22, after there had been ample time for the flies to emerge and oviposit, whereupon it

was removed. As a result of this experiment, from all of the flies developing from the transplanted wheat the offspring numbered but four individuals, showing quite conclusively that the Hessian fly can not develop in destructive abundance in that locality. This insect is destructively abundant west of the Cascade Mountains in Washington and Oregon, but not in the semiarid section to the eastward.

The distribution of the Hessian fly seems, therefore, to be controlled to a certain extent in the United States by conditions of humidity. Furthermore, the development of the fall generation appears to be governed to a certain extent by the same factor.

NATURAL ENEMIES.

There can be no doubt that parasites play a most conspicuous part in the natural control of the Hessian fly, and if we only knew the whole truth of the matter we should find that these minute friends of the

FIG. 11.—*Polygnotus hiemalis*, a parasite of the Hessian fly. Much enlarged. (Original.)

farmer are worth many times their weight in gold. Not infrequently one species of these parasites will overcome the pest in a neighborhood so effectively as almost to exterminate it. Several times the writer has found, in attempting to breed the Hessian fly from young wheat plants that had been killed by the larvæ, that hundreds of these parasites would emerge from the flaxseeds, while only an occasional fly could be obtained. Nearly all of these deposit their eggs in the bodies of the maggots, but the fully developed parasites emerge from the flaxseeds.

Prof. Herbert Osborn [1] has enumerated six species of these parasites, not including the English species *Entedon epigonus* Walker.

[1] Osborn, Herbert. The Hessian Fly in the United States. U. S. Dept. Agr., Div. Ent., Bul. 16, 58 p., 2 pl., 8 figs., 1898. See p. 28.

Polygnotus minutus Lindm., which occurs in Russia, France, and England, is in America represented by *Polygnotus hiemalis* Forbes (fig. 11), perhaps the most useful of any in this country. It is very minute, and Mr. Reeves has counted over 40 of the larvæ within a single flaxseed. It is black, with yellow feet, and the legs are dark brown, banded with yellow. The writer has again and again reared this in great numbers from fall wheat infested by the fly and witnessed the sudden check sustained by the pest the following spring. It is owing to this more than to any other influence that the Hessian fly is now being held in check in the spring-wheat regions of the Northwest, and it is probably due to a lack of this useful little insect that the serious invasion of the Hessian fly during the year 1914 was primarily due. From all the information at present available the severe winter of 1912 and 1913 so greatly reduced its numbers as to relieve the Hessian fly from the enormous restraint that it was at that time exerting upon the pest. A vast amount of material was secured during the summer and autumn of 1914 from which this parasite could have been reared had it been present. From nowhere over the entire section of the country infested by the Hessian fly, excepting in the State of Pennsylvania, have we been able to rear the parasite, and it seems almost beyond doubt that the losses from attacks of the Hessian fly during 1914, and such as may occur during the year 1915, will be due to the absence of this parasite in the wheat fields. The occurrence of the adult within the flaxseed of the Hessian fly is illustrated in figure 12.

FIG. 12.—Adults of Polygnotus which have developed within the "flaxseed" of the Hessian fly and are ready to emerge. Greatly enlarged. (Author's illustration.)

What appears to have been a most successful introduction of this beneficial insect was brought about some years ago in a shipment by Mr. E. O. G. Kelly from the Wellington, Kans., laboratory, to Mr. George I. Reeves in the State of Washington. Mr. Reeves liberated these parasites in fields badly affected by the Hessian fly. Up to that time he had not been able to secure this parasite in the State of Washington, whereas since the introduction of this insect from Kansas it has become not only very common, but in some cases abundant.

Another parasite reared almost invariably in connection with the Hessian fly is *Eupelmus allynii* French. (Fig. 13, male; fig. 14, female.) While this is generally distributed over the country and seems to be associated with the Hessian fly, and was for a long time supposed to be parasitic thereon, it now seems possible that it may be a secondary parasite and therefore the reverse of beneficial. It may be said, however, in its defense that it is most certainly a very important parasite of some other grain insects, notably the jointworms

and wheat straw-worms. The body is black with a greenish luster, and the legs are more or less yellow.

Merisus destructor Say (fig. 15) occurs in Europe, England, and America, but not in such profusion with us as to afford the same relief to the farmer as in the case of the preceding two. It also is black, but with a bluish-green metallic reflection, and the legs are black, banded with yellow.

Platygaster herrickii Pack. (fig. 16) is very minute, shining black in color, and is supposed by many to attack the egg of the fly, but there is still some doubt regarding this.

Baotomus subapterus Riley (fig. 17), as the name implies, has aborted wings in some individuals, while others are fully winged. The head

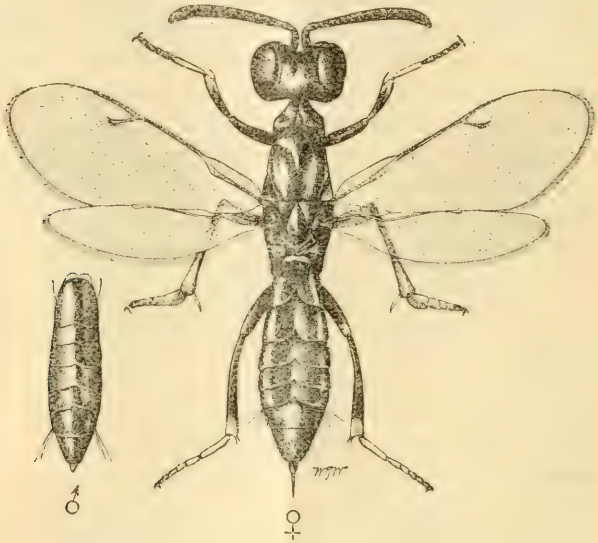

FIG. 13.—*Eupelmus allynii*, a parasite of the Hessian fly: Male. Much enlarged. (Original.)

and thorax are of a dark greenish metallic luster, and the legs honey-yellow. It is generally less abundant than some of the others, but sometimes individuals are quite numerous.

Besides these, several undescribed species have been recorded from the northwestern part of the country. The influence of these minute parasites in regulating the world's wheat supply is not at all understood, and it is doubtful if wheat could be successfully raised were they all to be suddenly swept out of existence.

REMEDIAL AND PREVENTIVE MEASURES.

Of remedies there is little to be said, since after the pest becomes established in a field it can not be reached by any measure likely to destroy it. The application broadcast of some quick-acting fertilizer containing a large percentage of phosphate, made as soon as general

infestation is apparent (see fig. 10), will cause the plants to tiller more freely and give them sufficient vigor to withstand the winter, and thus increase the number of healthy stems the following spring. Any other means that could be employed having a similar effect would be a remedial measure.

All practical measures must necessarily be in the nature of preventives, looking (1) to the elimination of the pest in the young wheat in the fall, and (2) to the increasing of the vigor of the young plants in order to enable them to counteract the insect's effect, when present. Under the first come late sowing, rotation of crops, burning of the old stubble, and the destruction of volunteer wheat. Under the second should be classed the enrichment of the soil, its thorough preparation, and selecting and properly sowing the best seed.

By late sowing as here recommended is meant moderately late sowing of fall wheat in any locality, for extremely late sowing, which has sometimes been advised, would be even worse than early sowing. The later appearance of the fly in the fall, as we pass from the north

FIG. 14.—*Eupelmus allynii*, a parasite of the Hessian fly: Female. Much enlarged. (Original.)

LATE SOWING.

southward, has already been explained. At present the Bureau of Entomology is conducting experiments in fall wheat sowing in nine States, covering approximately the country between latitude 33° and 46°. Here wheat is being sown every ten days during September, October, and November, year after year, with the expectation of determining the approximate date of safety for seeding in the fall to evade attack of the fly. While these experiments have not been going on for a long enough time to give results sufficiently definite, covering all variations in the weather during these months, it is safe to say that wheat may probably be sown, without danger from Hessian fly attack, in northern Michigan soon after the first of September; in southern Michigan and northern Ohio, about September 20; in southern Ohio, after the first week in October; in Kentucky and Tennessee, October 10 to 20; in Georgia and South Carolina, October 25 to November 15. In extreme southern Kansas and northern Oklahoma wheat should not be sown until after the first week in October; and this is true of Virginia. October-sown

wheat always enjoys the greatest freedom from the fly in Maryland. Practically the same corresponding delay in wheat sowing in the fall should be followed to the southward. So far these dates are only approximate, and serve to show in a general way about the time when the fall brood of the fly will have largely disappeared over the wheat belt east of the Mississippi River. As the larger part of the fall brood appears and is gone within a week, it is possible for a farmer so to time his seeding as to avoid it, and this is by far the most practical and effective preventive measure that can be applied.

CROP ROTATION.

Aside from the general benefits to be derived from crop rotation, this practice compels the Hessian fly, when it emerges from the

FIG. 15.—*Merisus destructor*, a parasite of the Hessian fly. Much enlarged. (Original.)

stubble in the fall (or spring in the Northwest), to travel a greater or less distance to reach young wheat plants.

If, during this season of migration, storms or heavy winds occur, these frail creatures will be driven about or beaten down until a comparatively small number survive to reach their destination. On the other hand, if they are not obliged to leave the field where they emerge, this mortality will be vastly lessened.

BURNING STUBBLE.

Burning the stubble is the most efficient measure of all, as fire will reach and destroy not only the Hessian fly but all other insects infesting the stubble, including the joint-worm. Unfortunately it can not be generally carried out. Over a large portion of the Middle West timothy and clover are sown, either with the wheat or during late winter or early spring, and therefore stubble-ground can not be burned over. Fields not followed by grass or clover can usually be burned over if the grain is cut rather high at harvest and a mower is

run over the field and the mown grass, weeds, and stubble allowed to dry for a few days just before the burning. This is much the more feasible measure in the Northwest, and ought to be more generally followed.

DESTRUCTION OF VOLUNTEER WHEAT.

Perhaps the importance of the destruction of volunteer wheat is best illustrated by the condition frequently observed in fields of young wheat in the fall, where every volunteer plant is infested and the sown grain is entirely free from attack. The volunteer plants were above ground in time to enable the fly to deposit her eggs on them, with the result that large numbers of flaxseeds will go through the winter and the flies therefrom will deposit their eggs on the plants which constitute the crop itself. Mr. C. N. Ainslie found 157 "flaxseeds" on a single volunteer wheat plant taken from a field in

FIG. 16.—*Platygaster herrickii*, a parasite of the Hessian fly. Much enlarged. (Original.)

southwestern Iowa in October, 1914. Thus the growth of volunteer plants menaces, to a certain degree, the crop of the following year, precisely as does a field sown too early more seriously menace adjoining fields that are uninfested in the fall. This destruction of volunteer plants by plowing, disking, or otherwise must take place before the larvæ have matured in order to be effective.

ENRICHING THE SOIL.

While it may seem "far fetched" to bring forward as a preventive measure the enrichment of the soil, a fertile soil will produce plants that will withstand with little injury attacks that will prove disastrous to plants growing on an impoverished or thin soil. This is because a fertile soil will enable an infested plant to tiller freely, and these tillers will have sufficient vitality to withstand the winter and send up head-producing stems in the spring. It is also chiefly on the thin or impov-

erished soils that the difficulty of sowing late enough to evade the fall attack and at the same time secure a growth sufficient to withstand the winter is encountered, and whatever can be done to obviate this difficulty will constitute a preventive measure.

PROPER PREPARATION OF THE SOIL.

It matters little whether a soil has much or little fertility if that fertility is bound up in clods or hard lumps out of reach of the rootlets of the young plants. Early plowing and thorough working and compacting of the soil will eliminate the lumps and clods and produce a finely pulverized, compact, moisture-conserving seed bed, from which, as soon as rootlets are sent out from the seed kernel, the shoot will begin to draw nourishment. This will give vigor to the plants and thus enable them, by freely tillering, to outgrow a light attack of the fly that otherwise might prove serious.

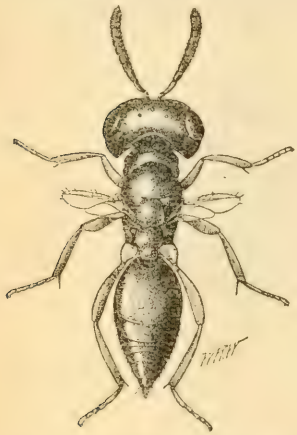

FIG. 17.—*Bradonus subpterus*, a parasite of the Hessian fly. Much enlarged. (Original.)

THE USE OF GOOD SEED.

When we come to consider the fact that the seed kernel contains, or should contain, sufficient nutriment to put out and sustain rootlets until these can begin to draw from the soil and thus support the stem, it will be seen at once that any deficiency in the seed will necessarily tend to weaken the plant at the very beginning of its existence. Thus good seed becomes the first requisite in securing the healthy, vigorous plant that is to be further strengthened and sustained by a well-prepared, fertile soil. It is very clear, then, that all shrunken, dwarfed, or otherwise imperfect kernels should be cleaned out of the seed before it is sown and only the largest and most perfect retained.

CONCLUSION.

Methods for controlling the Hessian fly, the worst pest of the wheat field, in the fall-wheat-growing sections may be summarized as follows: Sow the best of seed in thoroughly prepared, fertile soil after the major portion of the fall brood has made its appearance and passed out of existence, and, if possible, sow on ground not devoted to wheat the preceding year.

In the spring-wheat section late seeding will not apply. It seems likely, on the contrary, that the earlier it is sown in spring the less it will suffer from the Hessian fly. But good seed and a well-prepared, fertile soil are as essential there as elsewhere.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINTGTON, D. C. 649 FEBRUARY 27, 1915.

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

ALFALFA ATTACKED BY THE CLOVER-ROOT CURCULIO.

By F. M. WEBSTER,
In Charge of Cereal and Forage Insect Investigations.

INTRODUCTION.

The clover-root curculio[1] is of foreign origin and was not known to occur in America prior to 1876, when the late Dr. John LeConte found the beetles about the roots of grass growing on sand dunes at

FIG. 1.—Present known distribution in the United States of the clover-root curculio. (Original.)

Long Branch, N. J. Just when and by what means it was first brought into this country will of course never be known. It has, however, become widely diffused over the United States, as indicated

[1] *Sitones hispidulus* Fab.

NOTE.—In this bulletin attention is directed to the serious injury to clover and alfalfa caused by the clover-root curculio, and a description of the insect, its feeding habits, and remedial and preventive measures are given.

on the accompanying map (fig. 1), showing its known distribution up to the present time.

Several years ago studies were made of the insect and its attacks upon clover, although up to that time it had not been known to destroy this crop, or even to affect it seriously. Apparently, however, it was likely to become sufficiently abundant at any time to work serious injury, and for this reason Mr. V. L. Wildermuth, an assistant in cereal and forage insect investigations, prepared a paper which was published on March 7, 1910, as a bulletin of the Bureau of Entomology.[1] At that time there had hardly sufficient evidence accumulated to give this paper any considerable economic importance. It seems, however, that injuries that had either remained unnoticed or else had been placed to the credit of some other pests were partly or wholly due to the work of the larva or grub of this beetle. As this insect shows a disposition to occur in continually increasing abundance along roadsides and in clover fields, and as it has, during the last year, been found to commit serious depredations in fields of alfalfa, it seems desirable that printed information be made available for distribution among farmers, who are likely to suffer more or less from ravages of the pest.

FIG. 2.—The clover-root curculio: Adult. Greatly enlarged. (From Wildermuth.)

FIG. 3.—The clover-root curculio: *a*, Red clover root showing effects of attack by larva; *b*, red clover leaf showing work of adults. About natural size. (From Wildermuth.)

WHAT THE INSECT IS LIKE.

The fully developed insect is a beetle (fig. 2) which attacks the leaves of clover (fig. 3, *b*) and alfalfa. The line at the right of figure 2 shows the natural length of the beetle, and the eaten leaves (fig. 3, *b*) are plainly to be seen, especially during September

[1] Wildermuth, V. L. The clover-root curculio (*Sitones hispidulus* Fab.). U. S. Dept. Agr., Bur. Ent., Bul. 85, Pt. III, p. 29–38, fig. 15–19, March 7, 1910.

and October. They are particularly noticeable along roadsides, and the writer recently observed that in many cases the majority of the clover leaves in Middletown Valley between Mount Catoctin and South Mountain, Md., were eaten in this way, although the injury was not so noticeable in the clover fields adjacent. The most serious injury, however, is not to be charged to the beetle itself, but to the larva or grub.

FIG. 4.—The clover-root curculio: *a*, Egg immediately after deposition; *b*, egg one day after deposition. Greatly enlarged. (From Wildermuth.)

The eggs (fig. 4) are almost spherical, minute, and when first deposited are white, but after 24 hours change to a jet black. These eggs hatch to an almost equally minute white larva (fig. 5), the head of which is of a light chocolate brown. These grubs are without feet and therefore can not travel about readily. It is in this stage that the insect attacks the roots of clover and alfalfa and is particularly injurious. When this grub becomes full grown it passes from the grub stage into what is known as the pupal stage (fig. 6) during which it requires no food and consequently is not then injurious.

FIG. 5.—The clover-root curculio: Larva. Greatly enlarged. (From Wildermuth.)

SEASONAL HISTORY.

The clover-root curculio, as stated by Mr. Wildermuth, hibernates in the beetle form, hiding itself under rubbish and leaves on the surface of the ground, probably going into hibernation, in the latitude of Washington, some time in November. These beetles remain in their winter quarters until the first warm days of spring, when the females begin to lay their eggs upon the plants on the roots of which the young grubs are to feed. That these operations begin at the earliest possible date is shown by the fact that beetles were observed pairing near Hagerstown, Md., by Mr. H. L. Parker, on September 12, 1914, while Mr. Wildermuth found that beetles taken from the fields in October or November and kept in a warm room would produce eggs almost immediately; or if they are brought in during the winter, the same thing is observed to take place. No eggs or oviposition have been observed in the fields in the fall.

FIG. 6.—The clover-root curculio: Pupa. Greatly enlarged. (From Wildermuth.)

According to Wildermuth:

* * * the female deposits a large number of whitish eggs promiscuously on the leaves and ground or even on the side ofthe cage when confined. In the field eggs were found adhering to the lower leaves of botli red clover and alfalfa. Within less than a day these eggs change in color to a shining black. It is very probable, however, that in the natural state the eggs are usually deposited at or near the surface of the ground. The egg period is 13 days in duration. The larvæ immediately after hatching go down into the ground. Great trouble was experienced in getting eggs to hatch in rearing cages, and it seems from this that there may possibly be some other as yet unknown condition entering into egg deposition in the field.

The adult beetle endeavors to escape injury or capture by feigning death. If a clover plant upon which this beetle is resting be touched the beetle drops to the ground and lies there an inactive and almost invisible object. It is only when in motion that one is able to see it readily, since its color harmonizes so well with its surroundings.

The larval period varies from 17 to 21 days, the latter being apparently nearer the normal.

The pupal stage is passed in an earthen cell, which is oval in outline, about three-sixteenths of an inch (5 mm.) long, and half as large in diameter. The time required for the pupal stage is from 8 to 10 days, easily determined independently of the other two stages by collecting mature larvæ in the field and rearing them to adults.

The larval period was determined by getting the combined length of the egg, larval, and pupal periods and subtracting from these the number of days required for the egg and pupal stages. This method was followed because of the difficulty experienced in getting the newly hatched larvæ to live after being transferred from the vial in which the eggs were hatched to a clover plant on which they could feed, and also because of the fact that the more fully developed larvæ, when disturbed to any extent, nearly always died. Thus, to avoid this, a record was kept of the day of the egg deposition in a certain cage, and then the beetles were removed and the cage left undisturbed but watched carefully until adults appeared. The time required for this was from 38 to 43 days, thus making from 17 to 21 days for the larval stage.

It will therefore be seen that there is but one generation of this beetle annually in the North, but the fact that adults readily deposit eggs at any time after October or early November if placed in a warm room would indicate that there might be more than one generation in the warmer portions of the country, although of course this does not necessarily follow.

FEEDING HABITS.

The feeding habits are, so far as can be determined, almost exactly the same on alfalfa as upon clover. So far as the beetles are concerned the amount of food consumed is almost a negligible quantity, and it is only where they gather upon clover plants along roadsides that this sort of injury becomes conspicuous. In confinement Mr. Parker found that the beetles preferred alfalfa leaves to those of red clover, eating them more readily. So far as it has been possible to determine, the larvæ have precisely the same feeding habits on alfalfa that they have upon clover. Therefore the statements of Mr. Wildermuth which follow are as applicable to the one plant as to the other, and they are quoted herein in full.

The larvæ of this beetle feed on the roots of all the plants mentioned as food plants. The smaller, more tender, or fibrous roots are eaten by the younger larvæ which, as they become more mature, attack the larger roots. Large cavities are eaten along the main roots, and often these are in the form of a groove containing the feeding larva [fig. 3, *a*]. An examination of clover roots, made on September 23, showed clearly the after effects of the work of the larvæ. The roots were eaten at various places, some of them appearing as though the whole surface had been eaten off, the roots being scabby and brown, the damage having evidently been done during late spring or early in the summer.

The adults feed on the leaves, eating out irregular patches from the margin of the leaf [fig. 3, *b*]. They are not as hearty eaters as some of the allied species of beetles that live on clover, and hence their work is not so noticeable, except when the beetles have developed in excessively large numbers, as was the case at Corning, N. Y.

FOOD PLANTS.

The following paragraphs relating to the food plants of the clover-root curculio are quoted, in substance, from Mr. Wildermuth:

While the clovers seem to provide the natural food plants of this insect, there are reasons for believing that others may in future be added. This insect, when first observed in this country by Dr. LeConte, was reported by him as present around the roots of grasses growing on sand dunes. Stephens, in 1831, reported it in England as being abundant on sandy heaths, which were no doubt grown up with grass.

The writer, in the spring of 1908, found the larvæ in large numbers in a blue-grass pasture. These were, to all appearances, feeding partly on blue-grass roots, as the only clover present was the white, and this was rather scattering in the field. From this it would seem that some of the grasses may be host plants.

Of the clovers, red clover appears to be the most common choice as a food, while white clover, crimson clover, and alsike clover are all fed upon to a greater or less extent by both the adults and larvæ. Alfalfa seems to be a common food plant for both larvæ and adults. On June 17 the writer collected numerous larvæ from among alfalfa roots in a field at Somerset Heights, Md., and while sweeping over a field of alfalfa with an insect net at Muirkirk, Md., on April 28, experienced no difficulty whatever in securing from six to eight adults with each sweep of the net. It seems likely that, with the increasing acreage of alfalfa, this insect may become a destructive pest and also menace this crop. The fact that alfalfa is always grown continuously on the same land for a fairly long period, from three to six years, or even longer, may greatly accelerate the rapidity with which the insect will be able to increase in numbers.

RECENT DEPREDATIONS IN ALFALFA FIELDS.

Now it will be noted that at the time Mr. Wildermuth's paper was prepared the insect had not been observed as seriously affecting alfalfa. The first absolute proof that we were able to secure in this direction was on May 29, 1914, when Mr. J. L. Graybill, county demonstrator, of Phoenix, Md., brought to the bureau office specimens of the beetle, and also alfalfa plants that had been irretrievably damaged by some insect, either identical with the larvæ of this species or some other one working precisely like them. Mr. A. B. Gahan was at once dispatched to the infested fields and took up the investigation of the difficulty on June 4. On visiting an infested field it was

found that the hay crop had been cut the previous day and was lying on the ground. There appeared to be a good yield on some parts of the field, but there were many places where the alfalfa plants were very thin and evidently decidedly unhealthy. Upon examining the roots of the alfalfa on these injured areas the main taproots, and often the larger lateral roots, were badly injured. In some cases the injury consisted of a groove, generally of considerable length, up and down the root, but often of a round or oval patch. The injuries appeared to extend to a depth of 4 or 5 inches below the surface of the ground. In one case the taproot of the plant appeared to have been eaten entirely off several inches below the surface of the ground. On digging into the soil, the first shovelful of earth turned up revealed between 12 and 20 larvæ of this insect about the injured roots, and further investigation revealed their presence even more plentifully in other areas of the field. This condition was reported by Mr. Graybill as occurring throughout all parts of Baltimore County, Md.

At the time of this investigation the larvæ (fig. 5) and the pupæ (fig. 6) were present in about equal numbers. That is, the ravages of the pest were subsiding. In all cases both of these stages were within an inch, or at the most an inch and a half, of the surface of the ground. Later on—on July 6—complaints were received, with specimens, from Mr. George A. Billings, of West Chester, Pa. Here again considerable damage had been inflicted upon alfalfa. On consulting with agronomists we have found that either this or a very similar injury to alfalfa has been observed for several years, but no one heretofore appears to have traced this injury to its source.

Mr. C. N. Ainslie found the beetles excessively abundant in alfalfa fields in April, 1910, about Salt Lake City, Utah, but of course at that time the larvæ were not at work upon the roots of the plants, and while during later years other assistants in cereal and forage insect investigations found the adults abundantly in alfalfa fields at various points in Utah, none of them succeeded in securing the larvæ or observing their ravages on the roots. The work of the insect is so obscure that it is likely to escape completely the attention of alfalfa growers.

NATURAL CHECKS.

Our information relative to natural checks, as also that to bird enemies, has not changed materially since the publication of Mr. Wildermuth's paper, and therefore the statements made by him are quoted.

The larva was found to be attacked by a fungus, one of the Entomophthoræ, which no doubt assists in keeping the insects in check. The larvæ, because of their sluggish movements, might be easily captured and fed upon by predaceous beetles, but the fact that the larvæ and pupæ are subterranean in their habits is a semiprotection from parasitic insects as well as from many predaceous enemies. No Hymenopterous or Dipterous parasites were observed.

BIRD ENEMIES.

The Biological Survey, in its work on the food habits of birds, has found that the following birds feed upon the adults of this beetle: Upland plover, killdeer or killdee, ruffed grouse, broad-winged hawk, flicker, nighthawk, chimney swift, wood pewee, crow blackbird, meadowlark, Lincoln finch, song sparrow, chipping sparrow, and the white-throated sparrow.

Of these birds the chimney swift and song sparrow were found to be the greatest feeders on the insect, as many as 15 adult beetles being found in the stomach of one chimney swift, while but few less were found in stomachs of song sparrows.

REMEDIAL AND PREVENTIVE MEASURES.

Too short a period has elapsed since we have learned of the present and probably growing importance of this insect in the alfalfa fields to enable us to carry out extensive investigations of remedial and preventive measures.

This insect occurs generally throughout Europe and eastern Siberia as well as in England. It is known to be destructive in Europe to clover, but we have no records of serious damage to alfalfa outside of the eastern United States. Within the last year it has shown itself to be capable of working very serious damage in alfalfa fields and probably has been doing so for years, but on account of the obscure way in which the injury has been done its depredations appear to have escaped attention, although the effects upon the plants seem to have been noticed for a considerable time. If this condition can continue unobserved here in the East, there is no reason why it should not work serious ravages in the alfalfa fields throughout the entire United States where this crop is grown, and the cause of these ravages remain unnoticed even by experts. Now that we understand the nature and cause of these damages to alfalfa, it will be far easier to detect the work of the pest than has been heretofore the case. This bulletin is prepared for the especial purpose of calling the attention of alfalfa growers, county demonstrators, or other agricultural experts to its existence in this country, with the hope that the information will enable them to detect the pest in alfalfa fields and report its presence wherever found and in this way aid in anticipating and preventing as far as possible, by the most practical methods applicable under existing farm conditions, losses that might otherwise occur to alfalfa growers on account of the depredations of the insect in their fields.

Undoubtedly a short rotation of the alfalfa crop will have a tendency to limit the abundance of the pest in the fields. Of course this will not in any way affect the continuous breeding of the insect in waste lands or where clover or alfalfa occur uninterruptedly.

The limited amount of food consumed by the adults would of itself place the application of poisons out of practical consideration.

While the burning over of fields in winter when the ground is frozen might destroy some of the hibernating adults, in many cases they would probably be so near the soil, or so intermingled with the surface soil, as to escape the effects of the burning, and especially would this be true if they were further protected by a covering of matted green grass.

Therefore, at the present time the only practical suggestion that can be made is the disking or harrowing of the fields as soon as the first hay crop is removed. We know that the larvæ as a rule do not descend much more than an inch below the surface. If, therefore, the surface of the ground were disked and then harrowed, it would seem as though the pupal cells would be broken up, and as the pest is helpless in this stage, vast numbers would be destroyed in this way. While, as stated, there has not been sufficient time to carry out any exact experiments in this direction, it would be well for the farmers, until some better methods have been devised, to take the precaution of disking and harrowing immediately after removing the first hay crop in order to destroy as many as possible of the insects in their development. This, of course, can not be done early enough in the season to prevent injury, but it will in all probability reduce largely the abundance of the pest the following season.

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE SAN JOSE SCALE AND ITS CONTROL.

By A. L. QUAINTANCE,

In Charge of Deciduous Fruit Insect Investigations.

CHARACTER OF INJURY.

The San Jose or Chinese scale [1] infests practically all portions of its host plants that are above ground—the trunk, limbs, and branches—and when abundant it may occur on the leaves and fruit. Injury results from the extraction, by the scale insects, of the juices of the plant. At first this merely checks growth, but as the insects increase in number the speedy killing of the branches and twigs follows, resulting finally in the death of the plants. In addition to the extraction, by the scales, of sap as food, the puncturing of the bark by the slender sucking mouth parts results in a diseased and often pitted condition: the inner bark, or cambium, shows a reddish discoloration, as exposed in cutting with a knife, and the bark itself may crack, in stone fruits exuding drops or masses of gum. A reddening effect is also much in evidence as red rings around the scales on the bark, especially of the apple and pear, and on the fruits of these plants, though not characteristic of any one scale species.

On peach the scales have a tendency to infest to a greater extent the older limbs and branches than the newer growth, such as the wood 1 year old. On apple and pear the terminal twigs are quite generally infested, and many of the young may find their way to the fruit, settling principally in the calyx and stem cavities. Most varieties of fruit trees and plants infested from the nursery perhaps never reach fruiting condition unless treatment be given them. Peach trees will usually be killed in two or three seasons, while pear or apple trees will maintain a feeble existence much longer.

[1] *Aspidiotus perniciosus* Comstock; order Hemiptera, suborder Homoptera, family Coccidæ.

This insect, on account of its great similarity to certain other species of scale insects, may not be positively determined except by specialists. The occurrence of diseased and dying branches showing severe scale infestation furnishes strong presumptive evidence of the presence of this pest, but specimens of infested twigs should be promptly submitted to a qualified person for examination.

The appearance of a three-year-old peach tree, presumably infested from the nursery, is shown in figure 1. The principal limbs have already been killed, although new shoots have developed. A tree in this condition generally may be saved by thoroughly pruning out

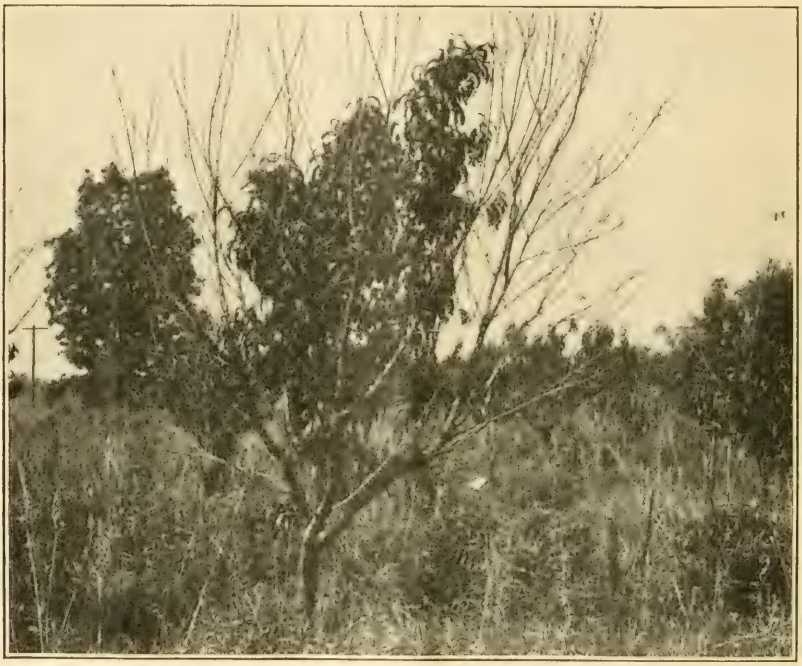

FIG. 1.—Appearance of 3-year-old peach tree badly injured by the San Jose scale, the larger branches having been killed. (Author's illustration.)

the dead and badly injured wood and subsequently effecting the control of the scale by spraying. The condition of this tree a year later is shown in figure 2, indicating the recovery following pruning and spraying. Figure 3 illustrates a badly infested six to seven year old peach orchard, the original infestation of which came from an adjacent orchard. Even in the case of peach trees so badly infested as these it is very probable that dehorning and thorough spraying would bring the trees into condition again. It is a matter of judgment, however, whether trees so seriously injured should not be removed.

The character of injury to an apple orchard, in which the trees were infested from outside sources four or five years earlier, is shown

in figure 4. Although many of the limbs and branches are injured or killed, such trees may be saved and brought into vigorous condition by thorough pruning and by insuring the control of the insect in the future.

THE INSECT DESCRIBED.

The mature San Jose scale is small, grayish in color, circular in outline, somewhat convex, and with a nipple-like prominence in the center. The female scale is about 1 millimeter in diameter (about the

FIG. 2.—Appearance of peach tree shown in figure 1, one year later. The dead and injured wood was thoroughly pruned out and the San Jose scale controlled by spraying. (Original.)

size of a pinhead); the male scale is much smaller and elongate. (See figs. 5 and 6.) The insect proper is beneath the so-called scale, this being simply a waxy covering secreted by the soft, helpless, yellow "louse" for its own protection. Where trees and plants are but slightly infested its presence is not readily detected by the casual observer, but in the case of severe infestation (see fig. 6) the bark of the tree

and limbs will present an ash-gray appearance, and on closer examination will be found thoroughly incrusted with the scales, which, when scraped with a knife, will produce a yellowish, oily fluid.

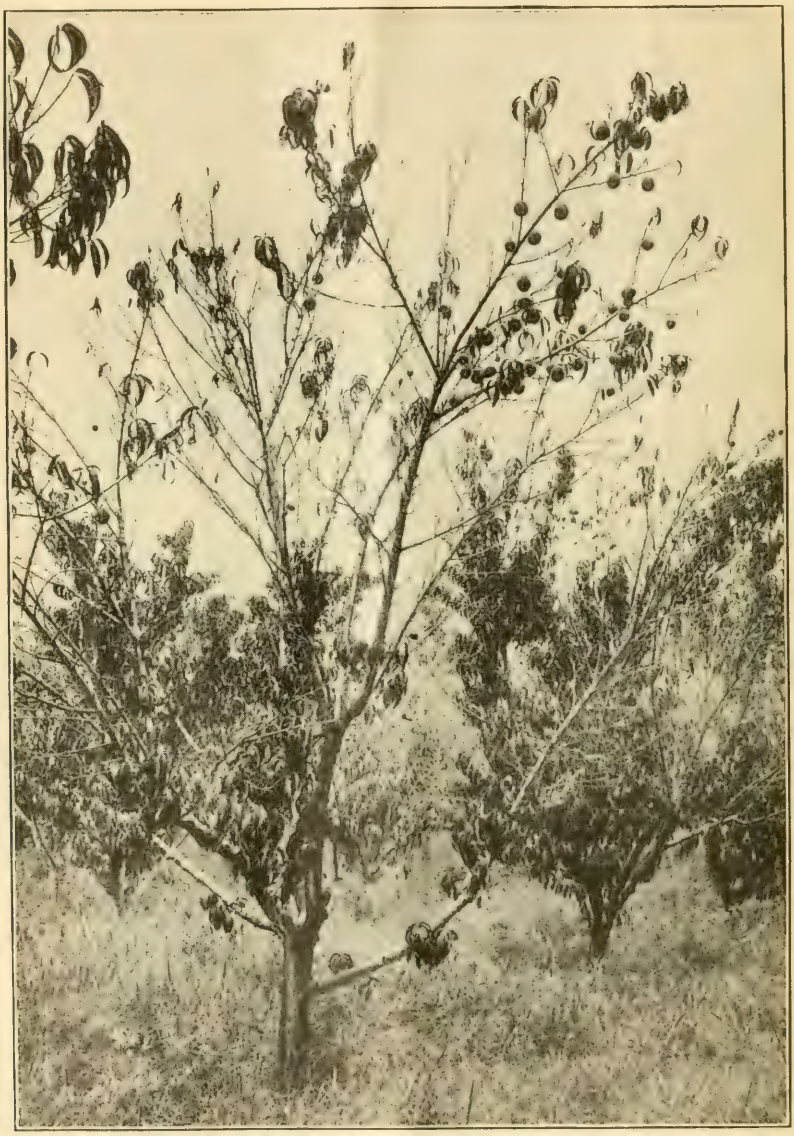

FIG. 3.—Appearance during summer of peach tree 6 to 7 years old badly injured by the San Jose scale. (Original.)

When the scales are abundant on the tree the foliage also will be thoroughly infested, giving it a spotted and diseased appearance readily observable some feet away.

NATURAL HISTORY AND HABITS.

The San Jose scale passes the winter in an immature condition fixed to the bark of the host plant, the small dark-gray or blackish scales being just discernible with the unaided eye. In early spring, with the ascent of the tree's sap, the growth of the scale begins, and early in April, in the latitude of Washington, D. C., the small, two-winged, active males issue from the male scales. After mating with the females the males die. The females continue to grow and in about a month begin the production of living young—minute,

FIG. 4.—Appearance of apple orchard badly infested by the San Jose scale; many of the limbs and branches have been killed. (Author's illustration.)

yellow, oval creatures which by very close observation may be distinguished without the aid of a hand lens, crawling here and there on the infested plants in an effort to find a suitable place for settlement. The young insect is active for some hours, but soon settles, pushes its slender, threadlike beak into the plant, and begins to feed by sucking out the sap. After this there is no further movement from place to place, and the waxy covering, which often begins to develop before the insect has settled, soon covers it completely.

In about 12 days the insects molt, and from this time on the male and female scales may be readily distinguished. From 8 to 10 days later the males change to pupæ, and in from 24 to 26 days from birth

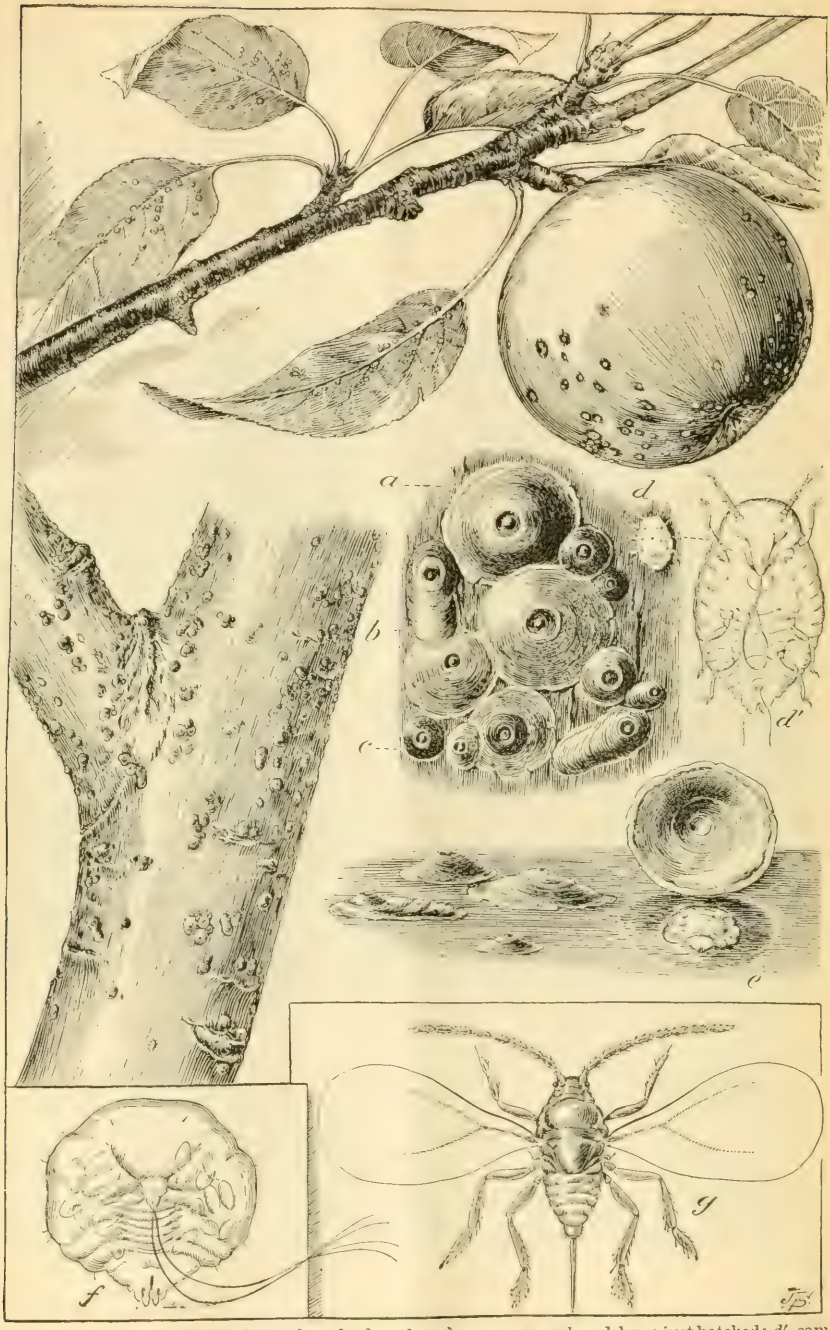

FIG. 5.—San Jose scale: *a*, Adult female scale; *b*, male scale; *c*, young scales; *d*, larva just hatched; *d'*, same, much enlarged; *e*, scale removed, showing body of female beneath; *f*, body of female insect, more enlarged; *g*, adult male of the San Jose scale. (Original.)

the adult males emerge and fecundate the females, which in turn reach maturity and begin the production of young in from 33 to 40 days from birth. An individual female may give birth, on the seasonal average, to about 400 young, and as the life cycle of the female covers but a few weeks there may be several generations a year, the number varying according to latitude. The progeny from one parent during the season have been estimated at 1,608,040,200 females. It is thus easy to understand how the insect can so quickly destroy the plants infested and why prompt remedial measures are so necessary. With the approach of the cool weather of fall, breeding

FIG. 6.—Enlarged view of a group of San Jose scales. (Original.)

gradually ceases and the scales in all stages enter hibernation. Most of the older and also most of the younger individuals perish during the winter, the survivors being those about one-third or one-half grown, as stated.

MEANS OF DISTRIBUTION.

The San Jose scale is distributed from one region to another principally on nursery stock, scions, or budding and grafting material. The danger of its dissemination in this way is fully realized, and laws are in force in the majority of States requiring the inspection of nurseries and the destruction of infested stock. Traffic in nursery produce is permissible only under the certificate of an official ento-

mologist or inspector that the stock is free from the scale. In addition to the actual inspection of nurseries, further safeguard is furnished by the practice of most nurserymen (compulsory in some States) of fumigating the plants, before distribution, with hydrocyanic-acid gas.

After the insect once becomes established in a locality its spread is accomplished by various agencies. As explained under the natural history of the insect, it is capable of movement only during a short period after birth. During this crawling stage the insects are able to pass from tree to tree where the limbs are in contact, but it is

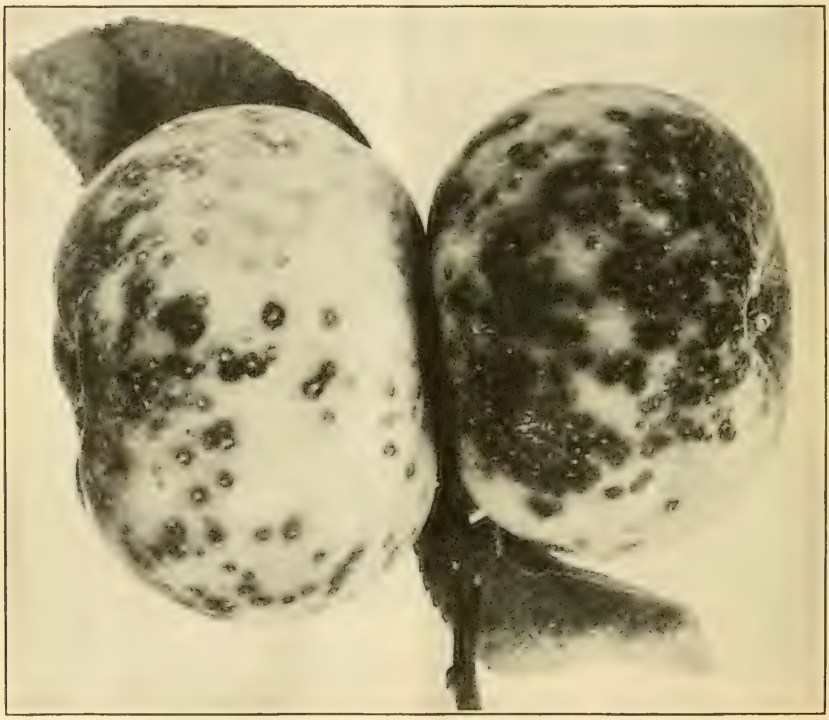

FIG. 7.—Appearance of apples infested with the San Jose scale. (Original.)

by agencies independent of itself that it is principally distributed. Prominent among these factors are birds, which may alight upon infested trees, where the young insects may crawl upon their feet and be subsequently deposited in other trees, sometimes at distances quite remote. It is probable that the young are blown by strong winds from tree to tree; and they are carried by insects, such as grasshoppers, ladybird beetles, ants, etc. The crawling "lice" may be transported considerable distances on the clothing of man, on vehicles, or on horses or other live stock which may be in orchards for any purpose.

The suggestion that the insect may be disseminated by means of scale-infested fruit (see fig. 7) has been frequently made, but it is the consensus of opinion among American entomologists that this danger is negligible.

FOOD PLANTS.

The San Jose scale infests practically all deciduous fruit trees, such as apple, pear, peach, plum, etc., and also many ornamental and shade trees. It is, however, seriously destructive to a much smaller number than that upon which it may actually maintain its existence. The following list of food plants, as compiled by Dr. W. E. Britton,[1] includes those that are commonly or badly infested:

Acacia sp. Lintner, Felt, N. Y.; Alwood, Va.
Akebia sp. Felt, N. Y.
Akebia quinata Decaisne. Alwood, Va.
Shad-bush (*Amelanchier canadensis* Medic.), Juneberry, and other species. Britton, Koehler, Conn.; Alwood, Va.
Citrus trifoliata Linn. Scott, Ga.; Alwood, Va.; Gossard, Fla.
Cornus alba Linn. var. *sibirica* Lodd. Britton, Conn.
Cornus baileyi Coult. & Evans. Gould (in N. Y.).
Cornus sanguinea Linn. Britton, Conn.
Cotoneaster sp.? Britton, Conn.; Lintner, Felt, N. Y.; Card, R. I.
Cotoneaster vulgaris Lindl. Alwood, Va.
Hawthorn (*Cratægus* sp.). Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Smith, N. J.
Cratægus cordata Soland. Koehler, Conn.
English hawthorn (*Cratægus oxyacantha* Linn.). Britton, Koehler, Conn.
Cratægus coccinea Linn. Koehler, Conn.
Cratægus crus-galli Linn. Koehler, Conn.
Common quince (*Cydonia vulgaris* Pers.). Britton, Conn.; Lintner, N. Y.; Alwood, Va.
Japanese or flowering quince (*Cydonia japonica* Pers.). Britton, Koehler, Conn.; Lintner, N. Y.; Alwood, Va.; Johnson, Md.
European purple-leaved beech (*Fagus sylvatica* Linn. var. *purpurea* Ait.). Smith, N. J.
Japanese walnut (*Juglans sieboldiana* Maxim). Britton, Conn.; Alwood, Va.; Sherman, N. C.; Smith, N. J.
Common privet (*Ligustrum vulgare* Linn.). Alwood, Va.
Poplar (*Populus* sp.). Britton, Conn.; Smith, N. J.; Sanderson, Del.; Felt, N. Y.
Carolina poplar (*Populus deltoides* Marsh). Britton, Conn.; Rolfs & Quaintance, Fla.; Alwood, Va.
Lombardy poplar (*Populus nigra* Linn. var. *italica* Du Roi). Britton, Koehler, Conn.; Rolfs & Quaintance, Fla.; Alwood, Va.
Almond (*Prunus amygdalus* Stokes). Lintner, N. Y.; Alwood, Va.
Apricot (*Prunus armeniaca* Linn.). Lintner, Felt, N. Y.; Alwood, Va.; Smith, N. J.
Sweet cherry (*Prunus avium* Linn.). Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Smith, N. J.; Cockerell, N. Mex.
Prunus pumila Linn. Koehler, Conn.
Sand cherry (*Prunus pumila* var. *besseyi* Waugh). Alwood, Va.
Purple-leaved plum (*Prunus cerasifera* Ehrh. var. *atropurpurea* Dipp. (*P. pissardi*). Britton, Conn.; Felt, N. Y.

[1] Britton, W. E. List of hardy trees, shrubs, and vines commonly or badly infested [by the San Jose scale]. Conn. Agr. Expt. Sta., Rpt. for 1902, pt. II., 2d Rpt. State Entomologist, p. 132–138. 1903.

European plum (*Prunus domestica* Linn.). Britton, Conn.; Alwood, Va.
Wild goose plum (*Prunus hortulana* Bailey). Alwood, Va.
Flowering almond (*Prunus japonica* Thunb.). Britton, Conn.; Felt, N. Y.
Beach plum (*Prunus maritima* Waugh). Koehler, Britton, Conn.
Peach (*Prunus persica* Sieb. & Zucc.). Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Cockerell, N. Mex.
Japanese plum (*Prunus triflora* Roxbg.). Britton, Koehler, Conn.; Alwood, Va.
Prunus serotina Ehrh. Koehler, Conn.
Chokecherry (*Prunus virginiana* Linn.). Koehler, Conn.
Hop tree (*Ptelea trifoliata* Linn.). Fernald, Mass.
Pear (*Pyrus communis* Linn.). Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Cockerell, N. Mex.
Sand pear, including Kieffer (*Pyrus sinensis* Lindl.). Alwood, Va.
Pyrus baccata Linn. Koehler, Conn.
Apple (*Pyrus malus* Linn.). Britton, Koehler, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Doten, Nev.; Cockerell, N. Mex.
Crab apple (*Pyrus* sp.). Britton, Conn.
Gooseberry (*Ribes oxyacanthoides* Linn.). Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.; Troop, Ind.
Missouri or flowering currant (*Ribes aureum* Pursh.). Lintner, N.Y.
Currant (*Ribes rubrum* Linn.). Britton, Conn.; Lintner, Felt, N. Y.
Black currant (*Ribes nigrum* Linn.). Alwood, Va.
Rosa sp. Britton, Conn.; Lintner, N. Y.; Alwood, Va.; Cockerell, N. Mex.; Burgess, Ohio; Troop, Ind.; Gould, Md.; Scott, Ga.
Rosa carolina Linn. Koehler, Conn.
Rosa lucida Ehrh. Koehler, Conn.
Rosa virginiana Mill. Koehler, Conn.
Rosa rugosa Thunb. Britton, Koehler, Conn.
Willow (*Salix* sp.). Britton, Conn.; Felt, N. Y.; Sanderson, Del.
Salix lucida Muhl. Koehler, Conn.
Laurel-leaved willow (*Salix pentandra* Linn.). Lintner, N. Y.; Alwood, Va.
Salix vitellina Linn. Koehler, Conn.
Weeping willow (*Salix babylonica* Linn.). Lintner, N. Y.; Alwood, Va.
Salix humilis Marsh. Koehler, Conn.
Salix incana Schrank. Koehler, Conn.
Mountain ash (*Sorbus* sp.). Felt, N. Y.; Hunter, Kans.
American mountain ash (*Sorbus americana* Marsh). Britton, Koehler, Conn.; Alwood, Va.
European mountain ash (*Sorbus aucuparia* Linn.). Britton, Koehler, Conn.
Black chokeberry (*Sorbus melanocarpa* C. Koch [*Aronia nigra* Koehne]). Koehler, Conn.
Snowberry (*Symphoricarpos racemosus* Michx.). Felt, N. Y.; Smith, N. J.
Common lilac (*Syringa vulgaris* Linn.). Burgess, Ohio; commissioner of agriculture, N. Y.; Troop, Ind.; Alwood, Va.
Persian lilac (*Syringa persica* Linn.). Britton, Conn.
Basswood, linden (*Tilia* sp.). Britton, Conn.; Lintner, commissioner of agriculture, N. Y.
American linden or basswood (*Tilia americana* Linn.). Britton, Conn.; Alwood, Va.
Osage orange (*Toxylon pomiferum* Raf.). Britton, Conn.; Lintner, Felt, N. Y.; Alwood, Va.
Elm (*Ulmus* sp.). Lintner, N. Y.; Webster, Ohio; Troop, Ind.
American elm (*Ulmus americana* Linn.). Britton, Koehler, Conn.; Alwood, Va.
English or European elm (*Ulmus campestris* Smith). Britton, Conn.; Felt, N. Y.; Smith, N. J.

This list might be materially extended by recording those plants upon which the insect has at various times been taken but to which it is not especially injurious. The fears earlier expressed that the scale would eventually seriously infest our native forest growth have not been borne out, and in effect it requires treatment only on fruit trees, bush fruits, and ornamental trees and plants.

NATURAL ENEMIES.

The San Jose scale is subject to attack by numerous predaceous and parasitic enemies, which render important service in its control. Practically, however, the combined influence of these several agen-

FIG. 8.—The pitiful ladybird: *a*, Beetle; *b*, larva; *c*, pupa; *d*, blossom end of pear, showing scales with larvæ of ladybird feeding on them, and pupæ of ladybird attached within the calyx. All greatly enlarged. (From Howard and Marlatt.)

cies is not sufficient to make up for the enormous reproductive capacity of this insect. To preserve the plants from destruction, its control must be accomplished by artificial means, such as the use of sprays.

Among the more common predaceous insects which are observed feeding on the scale is the so-called pitiful ladybird,[1] illustrated in figure 8. This very small, convex, black beetle may generally be found by any observant person on scale-infested trees.

Another species that feeds very commonly on this and other scale insects is the twice-stabbed ladybird.[2] This is a very near relative

[1] (*Pentilia*) *Microweisea misella* Lec.

[2] *Chilocorus bivulnerus* Muls.

and almost identical in appearance with the Asiatic ladybird[1] (fig. 9), which was introduced into this country from China through the activities of Mr. C. L. Marlatt, of the Bureau of Entomology, in the hope that its introduction would result in the control of this insect. The Asiatic ladybird, however, unfortunately proved to be subject to certain native parasites, while the necessity of spraying for the scale destroyed its food supply to such an extent that it was unable to maintain its existence.

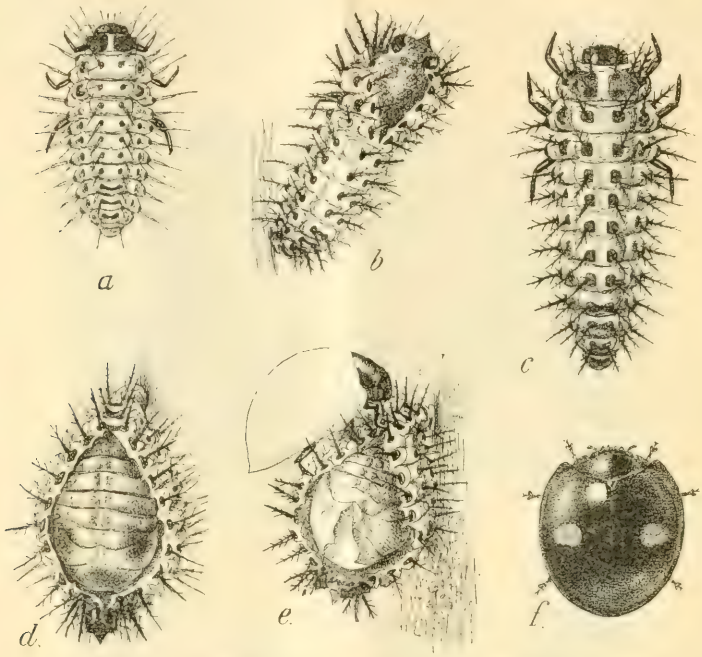

FIG. 9.—The Asiatic ladybird, almost identical with the twice-stabbed ladybird, predatory on the San Jose scale: *a*, Second-stage larva; *b*, cast skin of same; *c*, full-grown larva; *d*, method of pupation, the pupa being retained in the split larval skin; *e*, newly emerged adult not yet colored; *f*, fully colored and perfect adult. All enlarged to the same scale. (From Marlatt.)

In addition to the enemies just mentioned, there are certain very minute, four-winged flies (see fig. 10) belonging to the parasitic Hymenoptera, which are true parasites of scale insects. These place their eggs beneath the scales, some species attacking the scale insect while others attack the eggs. The resulting grubs kill the insect or devour the eggs. When the parasite has become fully developed it escapes through a small, round hole which it gnaws through the scale. Parasitism of the San Jose scale by these insects can be determined by inclosing in a glass vial a badly infested twig, for in the course of a few days the minute flies, if present, will begin to emerge. Dr. L. O. Howard and Mr. R. A. Cushman have prepared the

[1] *Chilocorus similis* Rossi.

following list of parasites which have been reared from the San Jose scale: *Aphelinus fuscipennis* How., *Aphelinus mytilaspidis* LeB., *Aphelinus diaspidis* How., *Aspidiotiphagus citrinus* How. (fig. 10), *Anaphes gracilis* How., *Physcus varicornis* How., *Prospaltella aurantii* How., *Prospaltella perniciosi* Tower, *Prospaltella fasciativentris* Gir., *Ablerus clisiocampae* Ashm., *Rhopoideus citrinus* How., *Perissopterus pulchellus* How., *Arrhenophagus chionaspidis* Auriv., *Anagrus spiritus* Gir., *Signiphora nigrita* Ashm., *Coccophagus immaculatus* How., *Coccophagus lecanii* Fitch, and *Microterys* sp.

While the benefits arising from the work of these parasites are undoubtedly great, the percentage of control of the scale thus accomplished varies greatly with the locality and the time of year, and from season to season. The highest percentage of parasitism thus far observed, and far in excess of the average, is 90. The remaining

FIG. 10.—*Aspidiotiphagus citrinus*, a hymenopterous parasite of the San Jose scale. Greatly enlarged. (From Howard.)

10 per cent of healthy scales would suffice for reproduction of the scale in injurious numbers. It is, therefore, readily seen that, even with this high percentage of parasitism, the control of the scale by these agencies can not be depended upon.

Considerable attention has been given to the subject of fungous diseases of the San Jose scale, and numerous attempts conducted in a thoroughly scientific manner, notably by Prof. P. H. Rolfs, director of the Florida Agricultural Experiment Station, have been made to utilize one of these parasitic plants in the control of the insect. The fungus in question, *Sphaerostilbe coccophila*, is cosmopolitan in its distribution, infesting many armored scale insects,[1] and in Florida and the territory adjacent to the Gulf it is quite generally present on scales in orchards and on shade and forest trees. Its abundance and effectiveness, however, depend upon certain weather conditions, and therefore vary considerably.

[1] Subfamily Diaspinæ.

CONTROL MEASURES.

As has been already stated, the San Jose scale, in the absence of proper treatment, will quickly bring about the death of many plants of economic importance. Its discovery, therefore, whether in orchards or on prized fruit trees and other plants in the yard, should call for prompt steps toward its control. It has been amply demonstrated that the scale may be very successfully controlled, and practically its presence merely requires one thorough treatment during the dormant period each year. On account of the general distribution of the pest extermination measures are, in most cases, out of the question.

Complaint sometimes comes from orchardists who have the scale to contend with that the control of the insect is neglected by their neighbors, and they believe this neglect adds materially to their own work. Undoubtedly the scale will spread from orchard to orchard, but thorough annual sprayings will prevent important injury irrespective of neglect in adjacent orchards.

Where plants are thoroughly incrusted, with consequent death of branches and stunting of growth, it will generally be advisable to dig out the trees at once and replace with new ones. Before spraying infested trees the dead and weakened wood should be pruned out, which will simplify the work of spraying and will hasten the formation of new, sound wood.

THE WASHES IN USE AGAINST THE SAN JOSE SCALE.

There are several scale washes which may be employed in the control of the insect, and the one should be selected which can be most conveniently used and which is economical under the circumstances. Thus, for spraying on a large scale, the orchardists could properly afford expenditures for the construction of cooking outfits for lime-sulphur wash which would not be justified where only a few trees were involved. For a few plants it would be better to use some one of the prepared washes put up by manufacturers. In fact, many large orchardists prefer to use sprays of this class in preference to making the washes at home. The possibility of injury to the trees from the sprays must also be borne in mind. All treatments, if possible, should be made during the dormant period (that is to say, in late fall or early spring, or even during the winter in mild climates), since at this time washes may be applied at much greater strengths than when the trees are in foliage. The aim is to use the wash about as strong as the tree will stand, thereby securing the maximum killing effect upon the insects. Used in this way the washes of the petroleum or kerosene series are most likely to cause injury to the fruit buds and tender twigs, and the lime-sulphur washes least likely to do so. Fish-oil soap sprays as recommended for dormant trees are comparatively safe, though reports are at hand of injury to

fruit buds, especially from fall applications. Stone fruits, such as peach, plum, etc., are more susceptible to injury from sprays than apple and pear, and on the former the lime-sulphur sprays should always be used. Petroleum and miscible oils are more frequently used on apple and pear, and owing to their spreading and penetrating qualities are perhaps more effective in destroying the scales on the terminal twigs, which are infested to a greater extent in the case of these fruits. The several sprays in use may be considered under the following headings: (1) Lime-sulphur wash series; (2) petroleum-oil series (including miscible oils), and (3) soap washes.

LIME-SULPHUR WASH SERIES.

For several years the cooked lime-sulphur wash was the main reliance in the control of the scale. It is made according to the following formula:

Stone lime	pounds	20
Sulphur (flour or flowers)	do	15
Water to make	gallons	50

Heat in a cooking barrel or vessel about one-third of the total quantity of water required. When the water is hot add all the lime and at once add all the sulphur, which previously should have been made into a thick paste with water. After the lime has slaked, about another third of the water should be added, preferably hot, and the cooking should be continued for one hour, when the final dilution may be made, using either hot or cold water, as is most convenient. The boiling due to the slaking of the lime thoroughly mixes the ingredients at the start, but subsequent stirring is necessary if the wash is cooked by direct heat in kettles. If cooked by steam, no stirring will be necessary. After the wash has been prepared it must be well strained as it is being run into the spray tank. It may be cooked in large kettles, or preferably by steam in barrels or tanks. This wash should be applied promptly after preparation, since, as made by this formula, there is crystallization of the sulphur and hardening of the sediment upon cooling. Probably comparatively few fruit growers at the present time prepare the wash according to this old method, but employ the commercial or homemade concentrate.

Commercial Lime-Sulphur Concentrates.

The inconvenience experienced in preparing the lime-sulphur wash according to the foregoing formula by cooking with steam or in open kettles at home has been one of the principal objections to this spray. Manufacturers have, therefore, put on the market concentrated solutions of lime-sulphur which have only to be diluted with water for use. These commercial washes, if used at proper strength, have proved to be quite as satisfactory in controlling the scale as

the old-formula lime-sulphur wash, and, although somewhat more expensive, have been adopted by many of the commercial orchardists in preference to the "20–15–50" formula. They are especially useful for the smaller orchardists whose interests do not warrant the construction of a cooking plant.

Homemade Lime-Sulphur Concentrates.

The question of the preparation at home of concentrated lime-sulphur solutions which will not crystallize upon cooling, thus duplicating the commercial product, has been investigated by the Bureau of Entomology, as well as by numerous experiment station entomologists, notably by Profs. Stewart, Cordley, Parrott, and others. It has been demonstrated that it is practicable for orchardists to prepare concentrated stock solutions of lime-sulphur wash for immediate or later use, and many orchardists employ this plan. The necessary details for the preparation at home of lime-sulphur concentrates are given below.

DIRECTIONS FOR PREPARATION OF LIME-SULPHUR CONCENTRATES.

The so-called 50–100–50 formula, composed of 50 pounds of lime, 100 pounds of sulphur, and water to make 50 gallons, has been generally recommended for the preparation of a homemade concentrated lime-sulphur solution. Some advise the use of five or six pounds of sulphur more than above stated in order to have a slight excess of this ingredient over the lime. The method of preparation is to boil together in the necessary water the respective ingredients for from 50 minutes to an hour. A good grade of fresh stone lime containing not less than 90 per cent of calcium oxid is necessary for the best results. Hydrated lime is sometimes used, but it is necessary to use a good grade and at least 20 per cent more of this form of lime is required, as it contains a high percentage of moisture.

Place enough water in the cooking vessel to finish with 50 gallons of the solution; bring the water to the boiling point, then put in the lime and immediately add the sulphur. If the plant is equipped with an agitator, this should be started with the addition of lime and sulphur. If there is no mechanical agitator, the mixture must be stirred vigorously by hand until the lime is slaked, and necessary agitation must be given throughout the time of cooking. If the solution is to be put in barrels without filtering, it should be drawn off as soon as the period of cooking is completed, and allowed to run through a 30-mesh strainer into the barrels. The agitation should be continued while the solution is being drawn off so that there will be an equal distribution of the sludge in the different storage receptacles.

The density of the concentrate, made according to the formula 50–100–50, has varied, in the experience of the Bureau of Entomology, from 24 to 28 degrees Baumé, and theoretically should be 26° by this scale. It is quite desirable for economy in storage space to prepare as highly concentrated a solution as possible. This can be done with reduced quantity of water after the following formula, which will give a solution of a density of from 32 to 34 degrees Baumé.

Fresh stone lime	pounds	80
Commercial ground sulphur	do	160
Water to make, of the finished product	gallons	50

While this formula gives about 50 per cent in volume of sludge, after allowing the solution to settle for 24 hours, there is only about 5 to 10 per cent in volume of insoluble material, which would be removed in the straining process. This volume of sludge will not be objectionable in spraying, provided the insoluble material has been properly strained out.

HANDLING AND STORAGE.

It is very desirable in most cases to make up a supply of lime-sulphur solution during the winter or early spring, before spraying operations begin. It is quite feasible to do this, as the solution can be kept a year or more when properly stored. It should be placed in barrels or other tight receptacles and carefully stoppered so as to exclude the air as much as possible, as this slowly causes the wash to deteriorate. The barrels or other container should be completely filled, so that there will be little or no air space above the surface of the liquid. In the preparation of the lime-sulphur concentrate at home the disposition of the sludge is a question of practical importance. Commercial manufacturing plants are usually supplied with a filter press by means of which the wash, as it comes from the cooking tank, is filtered, freeing it from sludge and sediment. There seems, however, to be no objection to storing the solution without removal of sludge, though the sediment should be strained out as already stated.

Lime-sulphur solution should not be allowed to freeze, as this greatly reduces its strength. It does not freeze easily, however, and the temperature at which it freezes varies with its strength; the stronger the solution, the less easily it is frozen. It will stand a considerably lower temperature without freezing than will water.

COOKING PLANTS.

Lime-sulphur concentrate may be made by orchardists with very simple appliances, such as a large kettle suspended on a pole or raised from the ground on loose stones. One or two such kettles embedded in masonry would be more convenient, however, and would permit the

development of necessary facilities for water supply. (See fig. 11.) Ordinary feed cookers or jacketed kettles are also very satisfactory. Small steam boilers of a few horsepower capacity serve especially well for a medium-sized orchard.

Where the amount of concentrate to be made is considerable, as for a large orchard or for the fruit growers of a neighborhood, it will pay to construct a more elaborate cooking plant. A convenient outfit is shown in figure 12. In the construction of these plants careful attention should be given to the arrangement of the cooking vessel, the water supply, and the arrangement for drawing off the cooked wash. A

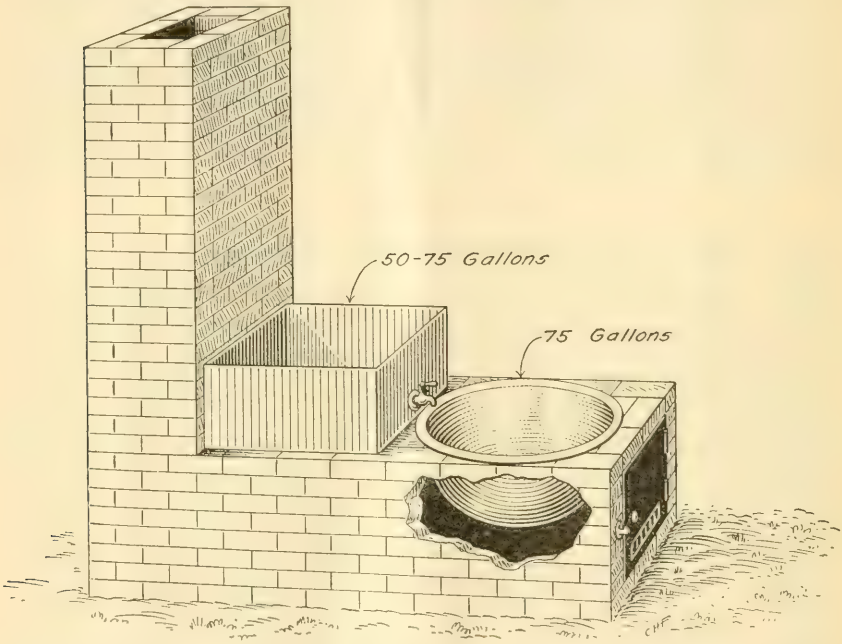

FIG. 11.—Lime-sulphur cooking outfit for preparing wash for small to medium sized orchards. Prepared by E. W. Scott. (Original.)

12-horsepower boiler will furnish sufficient steam for a cooker of 300 gallons capacity. However, if a steam engine is to be used for running the agitator, a somewhat larger boiler will be necessary. The cooking vessel may be either of wood or iron, though an iron vessel is usually more satisfactory owing to the difficulty in preventing leakage of wooden vessels. If the cooking vessel is not provided with a pump it should be so elevated that the cooked concentrate may be drawn off by gravity into a settling tank or storage vessels. Vinegar barrels, or barrels which have been used for acids, should not be employed in storing the solution, as the acid breaks down the concentrate. Kerosene oil barrels and whisky barrels are used to a large extent.

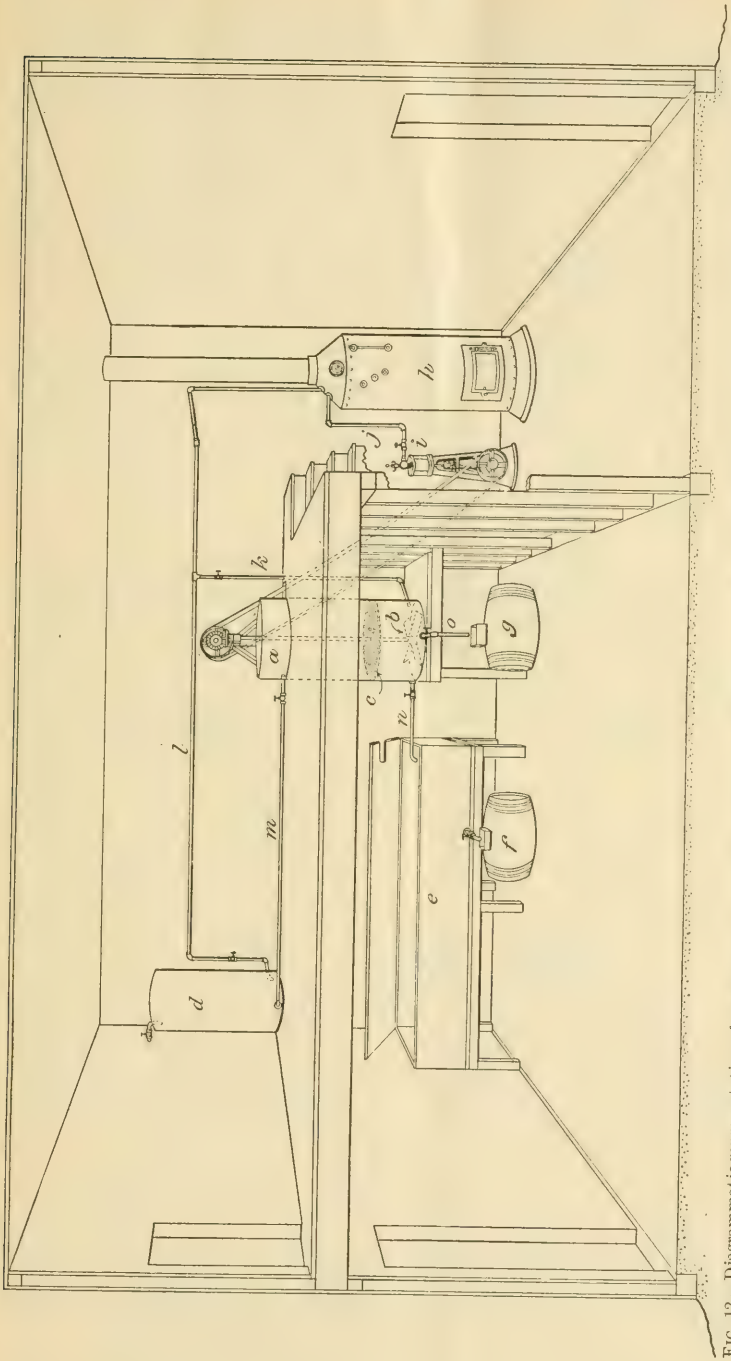

FIG. 12.—Diagrammatic representation of arrangement of parts in a large lime-sulphur cooking plant: *a*, Cooking tank; *b*, agitator; *c*, screen for support of lime and sulphur; *d*, water supply tank; *e*, settling tank; *f*, barrel for storing the lime-sulphur concentrate; *g*, same when concentrate is drawn directly from cooking vessel; *h*, steam boiler; *i*, steam engine for running agitator; *j*, steam pipe from boiler to engine; *k*, steam pipe for cooking the lime-sulphur concentrate; *l*, steam pipe for heating water in water supply tank; *m*, pipe from water supply tank to cooking vat; *n*, pipe and valve for drawing off concentrate from cooking vat to settling tank; *o*, pipe and valve for drawing off concentrate from cooking vat directly to storage barrel. Prepared by E. W. Scott. (Original.)

DILUTION.

It is very important to test with a hydrometer the strength of all lime-sulphur solutions prepared, to determine the proper amount of the concentrate that should be used for a given quantity of water. There are two kinds of these hydrometers, one with the Baumé scale and the other with the specific gravity scale, and hydrometers may be purchased which have both scales on the same instrument. The Baumé scale hydrometer is most commonly used. The clear solution at a temperature of about 60° F. should be used for the testing. If, however, the sludge has not been filtered out, the contents of the barrel or other container should be thoroughly stirred before the required amount for testing is taken out.

Below is given a table (Table I) from which can be determined the amount of dilution for concentrates for each degree Baumé from 20 to 36, and the corresponding specific-gravity reading. Figure 13 illustrates the kind of hydrometers to be used in testing lime-sulphur concentrates.

TABLE I.—*Dilution table for concentrated lime-sulphur solutions.*

Degrees Baumé.	Specific gravity.	Number gallons concentrated lime-sulphur to make 50 gallons spray solution.			Degrees Baumé.	Specific gravity.	Number gallons concentrated lime-sulphur to make 50 gallons spray solution.		
		Summer or foliage strength.	Winter or dormant strength.				Summer or foliage strength.	Winter or dormant strength.	
			San Jose scale.	Blister mite.				San Jose scale.	Blister mite.
36	1.330	1½	5¼	4¾	27	1.229	2	8	6¾
35	1.318	1¼	5¾	5	26	1.218	2	8½	7¼
34	1.306	1½	6	5	25	1.208	2	8¾	7½
33	1.295	1½	6¼	5¼	24	1.198	2¼	9¼	8
32	1.283	1½	6½	5½	23	1.188	2¼	9¾	8¼
31	1.272	1½	6¾	5¾	22	1.179	2¼	10¼	8¾
30	1.261	1¾	7	6	21	1.169	2½	11	9¼
29	1.250	1¾	7¼	6¼	20	1.160	2½	11½	9¾
28	1.239	1¾	7½	6½					

In spraying for the San Jose scale and the pear-leaf blister mite about 5 per cent more of the solution should be used than the table of dilutions indicates, if the sludge has not been filtered out. In summer spraying, however, no allowance for sludge is necessary, as a large percentage of this is composed of finely divided sulphur, which is of value.

LIME-SULPHUR WASHES FOR SUMMER SPRAYING OF THE SAN JOSE SCALE.

The lime-sulphur washes discussed on the preceding pages are intended for use on trees in a dormant condition. It sometimes happens that owing to unfavorable weather conditions during the time of the dormant spraying, or for other reasons, the insect has not been properly destroyed, and it becomes desirable to spray the trees during the

summer. Under these circumstances much benefit will follow summer spraying for the San Jose scale, but this work should be regarded as a temporary expedient to prevent undue increase of the insect until the more effective dormant treatment may be applied.

Either the commercial or homemade lime-sulphur concentrate may be used for summer spraying (except on stone fruits), but they must be used in a much more dilute condition than during the winter. The dilute lime-sulphur spray has come into very extended use as a fungicide[1] and is used on pome fruits at the rate of $1\frac{1}{2}$ gallons of the concentrate, registering from 32 to 34 degrees on the Baumé scale, to 50 gallons of water. The use of the lime-sulphur wash as a fungicide will constitute sufficient sprayings for the scale, provided attention is given in spraying to coat, in addition to the leaves and fruit necessary in fungicidal work, also the limbs, branches, and twigs.

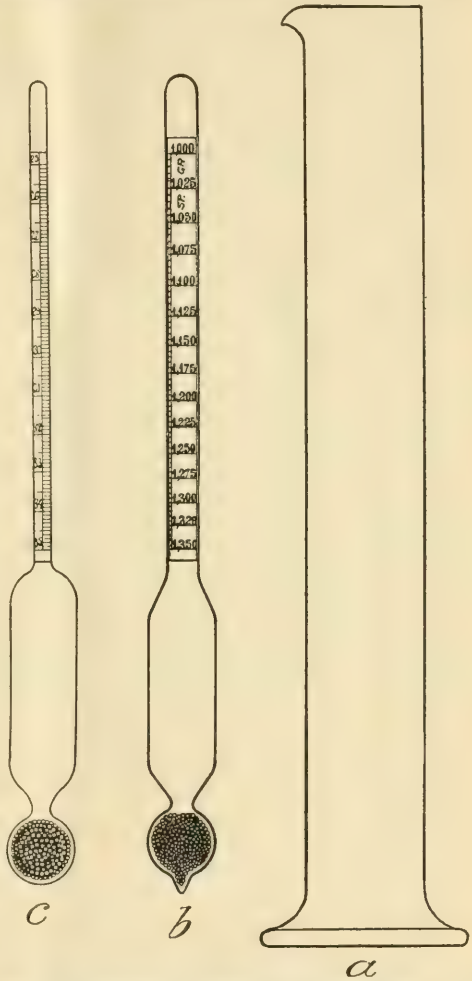

FIG. 13.—Apparatus for determining specific gravity of lime-sulphur concentrate: *a*, Cylinder for liquid to be tested; *b*, specific gravity spindle; *c*, Baumé spindle. (Original.)

Young scale insects from individuals which may have escaped the treatment have a decided tendency to migrate onto the fruit. The presence of these insects on the fruit is very objectionable, especially on apples intended for export trade, as scale-infested fruit is excluded from entry by certain foreign governments, and is discriminated against by buyers generally. The influence of sulphur sprays used as fungicides in trees and foliage in checking the settling of young scales on the fruit is shown in Table II. These data were obtained by Mr. E. W. Scott, of the Bureau of Entomology, in the course of some experimental work during 1911 at Fennville, Mich.

[1] Quaintance, A. L., and Scott, W. M. The more important insect and fungous enemies of the fruit and foliage of the apple. U. S. Dept. Agr., Farmers' Bul. 492, 48 p., 21 figs. 1912.

TABLE II.—*Results of lime-sulphur sprays in preventing marking of fruit by the San Jose scale.*

Plat No.	Treatments.[1]	Variety.	Number of apples infested.	Number of apples not infested.	Total number of apples.	Percentage of uninfested apples.
1	Commercial lime sulphur, 1½ to 50; sprayed May 12, 25, June 14, July 25.	Rhode Island Greening.	137	1,606	1,743	92.13
2	do	Baldwin	80	778	858	90.67
3	Home boiled lime sulphur, May 12, 25, June 14, July 25.	Greening	79	3,939	4,018	98.03
4	do	Baldwin	37	1,813	1,850	98.00
5	Commercial lime sulphur, 1½ to 50; May 12, 25, June 14, July 25.	do	13	298	311	95.81
6	Bordeaux mixture (3-4-50), May 12, 25, June 14, July 25.	Greening	843	1,055	1,898	55.58
7	do	Baldwin	525	500	1,025	48.78
8	Unsprayed	Greening	796	805	1,601	50.28
9	do	Baldwin	809	190	999	19.01

[1] All treatments had 2 pounds of arsenate of lead to each 50 gallons of spray, except in case of plat 5, which had the poison in the application of May 12 only.

Summer spraying of peach trees and other stone fruits for the scale may also be desirable because of ineffective work during the dormant period of the trees. Under such circumstances the self-boiled lime-sulphur mixture should be used, since the foliage of the peach will not stand the diluted lime-sulphur mixture previously indicated for the apple, pear, etc. This self-boiled lime-sulphur wash is made up according to quite a different formula from any of the washes heretofore mentioned, and has come into general use as a fungicide for the control of peach scab and brown-rot.[1] Orchardists spraying for these troubles on peaches and other stone fruits may at the same time accomplish much in preventing the increase of the scale by thoroughly coating the limbs and branches of the trees while making the applications to the foliage and fruit for the control of the fungous troubles mentioned. The self-boiled lime-sulphur wash may be made as follows:

Stone lime	pounds	8
Sulphur (flour or flowers)	do	8
Water to make	gallons	50

The lime should be placed in a barrel and enough water poured on almost to cover it. As soon as the lime begins to slake the sulphur should be added, after first running it through a sieve to break up the lumps. The mixture should be stirred constantly and more water added as needed to form a thick paste at first and then gradually a thin paste. The lime will supply enough heat to boil the mixture several minutes. As soon as it is well slaked water should be added to cool the mixture and prevent further cooking. It is then ready to be strained into the spray tank, diluted, and applied.

[1] Scott, W. M., and Quaintance, A. L. Spraying peaches for the control of brown-rot, scab and curculio. U. S. Dept. Agr., Farmers' Bul. 440, 40 p, 14 figs. 1911.

The stage at which cold water should be poured on to stop the cooking varies with different grades of lime. Some limes are so sluggish in slaking that it is difficult to obtain enough heat from them to cook the mixture at all, while other limes become intensely hot on slaking, and care must be taken not to allow the boiling to proceed too far. If the mixture is allowed to remain hot 15 or 20 minutes after the slaking is completed the sulphur gradually goes into solution, combining with the lime to form sulphids, which are injurious to peach foliage. It is therefore very important, especially with hot lime, to cool the mixture quickly by adding a few buckets of water as soon as the lumps of lime have slaked down. The intense heat, violent boiling, and constant stirring result in a uniform mixture of finely divided sulphur and lime, with only a very small percentage of the sulphur in solution. It should be strained to take out the coarse particles of lime, but the sulphur should be carefully worked through a strainer. The mixture can be prepared in larger quantities if desirable, say enough for 200 gallons at a time, making the formula 32 pounds of lime and 32 pounds of sulphur to be cooked with a small quantity of water (8 or 10 gallons) and then diluted to 200 gallons.

COMMERCIAL POWDERED SULPHUR COMPOUNDS.

Within the past two or three years certain manufacturers have offered for sale, in a dry powdered condition, compounds of sulphur which are to be dissolved in water for the preparation of the spray. These compounds give promise of being satisfactory as scale washes, and if so, will undoubtedly meet with prompt favor with orchardists, since by their use there is a distinct saving in freight, and they are much more convenient in handling and storing.

PETROLEUM-OIL SERIES.

Under the heading "Petroleum-oil series" are to be included kerosene and crude petroleum, either pure or in emulsion, and the so-called miscible oils.

Pure Kerosene.

Pure kerosene has been recommended to a greater or less extent for spraying trees badly infested with the scale, but it has never been very generally employed. There is no question of the efficiency of such an application in the destruction of the insects, but the great danger of injury to the plants precludes its general application. Treatments of pure kerosene should be made only to dormant trees and during bright days and should be applied through a nozzle with a very fine aperture. Only the minimum amount of kerosene necessary to cover the trees should be given, and care is necessary that the liquid does not puddle around the roots of the trees.

Pure Crude Petroleum.

Pure crude petroleum is used in identically the same manner as pure kerosene, and the same cautions as to its use should be remembered. The crude oil employed in the East is known as "insectide oil" and has a specific gravity of 43 to 45 degrees on the Baumé scale.

Kerosene Emulsion (Stock Solution 66 Per Cent Oil).

Kerosene emulsion is made after the following formula:

Kerosene (coal oil, lamp oil)	gallons	2
Fish-oil soap or laundry soap (or 1 quart of soft soap)	pound	$\frac{1}{2}$
Water	gallon	1

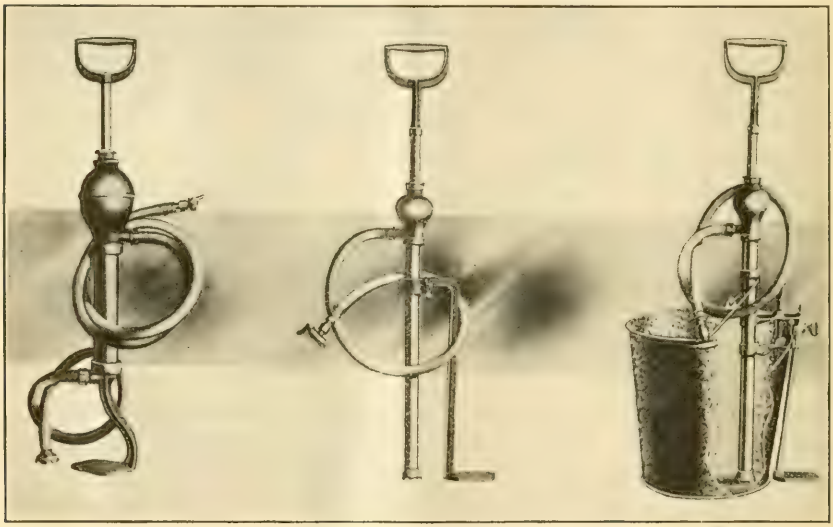

Fig. 14.—Bucket spray pump suitable for use in yards. (Author's illustration.)

Dissolve the soap in boiling water; then remove the vessel from the fire. Immediately add the kerosene and thoroughly agitate the mixture until a creamy solution results. The stock emulsion may be more conveniently made by pouring the mixture into the tank of a spray pump and pumping the liquid through the nozzle back into the tank for some minutes. The stock solution, if well made, will keep for some months, and is to be diluted before using. In order to make a 10 per cent spray (the strength for trees in foliage), add to each 1 gallon of the stock solution about $5\frac{2}{3}$ gallons of water. For 20 and 25 per cent emulsions (for use on dormant trees and plants), use, respectively, about $2\frac{1}{3}$ gallons and $1\frac{2}{3}$ gallons of water for each 1 gallon of stock emulsion. Agitate the mixture in all cases after adding the water. The preparation of the emulsion will be simplified by the use of a naphtha soap. No heat will then be required, as the kero-

sene will combine readily with the naphtha soap in water when thoroughly agitated. Of naphtha soap, however, double the quantity given in the foregoing formula will be required, and soft or rain water should be used in making the emulsion. In regions where the water is "hard" this should first be broken with a little caustic potash or soda, such as common lye, before use for dilution, to prevent the soap from combining with the lime or magnesia present, thus liberating some of the kerosene; or rain water may be employed.

Crude Petroleum Emulsion.

Crude petroleum emulsion may be prepared in identically the same way as described for kerosene emulsion, substituting crude petroleum for kerosene. The same dilutions for winter and summer

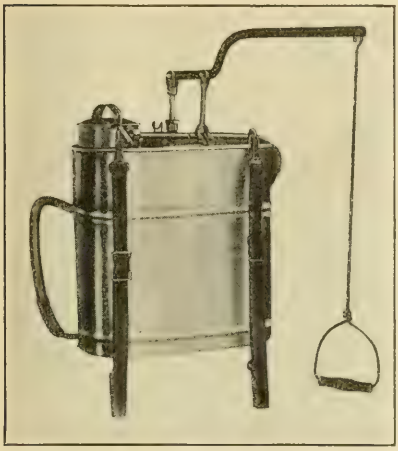

Fig. 15.—Knapsack sprayer suitable for spraying low-growing plants. (Author's illustration.)

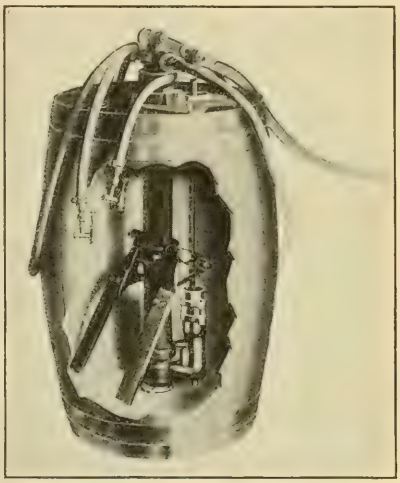

Fig. 16.—Barrel sprayer suitable for orchard or similar large-scale work. (Author's illustration.)

spraying should be made as prescribed for kerosene emulsion, but it should be noted that for summer treatments of trees in foliage the kerosene emulsion is preferable, as it is less likely to cause injury.

Miscible Oils.

Under the heading "miscible oils" are to be designated several proprietary preparations which are essentially petroleum oils with the addition of a vegetable oil and an alkali, to secure ready saponification with water. These come in concentrated solutions and the spray is prepared by adding a specified amount of water. In point of convenience they leave little to be desired. Miscible oils have come into use in place of kerosene or crude petroleum, either pure or in emulsions, and have a distinct usefulness as winter sprays about the same as have the concentrated lime-sulphur solutions. As has

been indicated, the petroleum oils are at times the cause of injury to twigs and fruit buds, in extreme cases killing the trees. It is a question of judgment whether, under conditions of severe scale infestation, the petroleum oils or the sulphur solutions should be used. The petroleum oils, on the whole, are more effective and the danger of injury from them is less to pome than to stone fruits.

The practicability of making miscible oils at home has been investigated by Prof. C. L. Penny, and he has shown it to be entirely feasible, as detailed in the publications cited below.[1]

FIG. 17 —Gasoline power spraying outfit for use in large orchards. (Original.)

SOAP WASHES.

Practically the only soap wash which has come into extended use against the San Jose scale is that made from fish oil. Fish-oil soap is used mostly on dormant trees, being employed at the rate of 2 pounds to the gallon of water.

A potash fish-oil soap is preferable and should contain not more than 30 per cent of water. Soda soaps, while perhaps cheaper, will be

[1] Penny, Charles L. Petroleum emulsions. Del. Agr. Col. Expt. Sta., Bul. 75, 39 p., June 18, 1906. Penny, Charles L. Miscible oils: How to make them. Penn. State Col., Bul. 86, 20 p., fig., March, 1908.

likely to solidify on cooling when used at the strength just indicated, and are hence forced through the spray-nozzle with difficulty. For spraying trees in foliage the soap should be used at the rate of 1 pound to 3 or 4 gallons of water, or somewhat weaker.

SPRAYING APPARATUS.

For the successful application of sprays to trees and plants infested with the San Jose scale some form of spraying apparatus is necessary. For small plants, as low trees, ornamental hedges, etc., a bucket pump (fig. 14) or a knapsack pump (fig. 15) will be satisfactory. The barrel pump (fig. 16) will permit of more thorough work and will be suitable for orchards of some size. It may be placed in a wagon or cart or mounted on a sledge. For large commercial orchards the hand-power tank, or gasoline outfits, are, of course, employed. (See fig. 17.) It is quite practicable in case but a few trees in the yard are to be treated to apply the wash on the limbs and branches by means of a brush, or even with old cloths. Fish-oil soap is excellent in such cases. Severe pruning of the trees is usually desirable to simplify the work of treatment, and also to produce a new growth of noninfested wood.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 657 MAY 6, 1915.

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE CHINCH BUG.[1]

By F. M. WEBSTER,

In Charge of Cereal and Forage Insect Investigations.

INTRODUCTION.

Few insects, and certainly no other species of the natural order to which this one belongs, have been the direct cause of such enormous pecuniary losses as the chinch bug (fig. 1). No other insect native to the Western Hemisphere has spread its devastating hordes over a wider area of country (see maps, figs. 6 and 7) with more fatal effects to the staple grains of North America than has this one. Were it not for the extreme susceptibility of the very young to destruction by drenching rains, and the less, though not insignificant, fatalities to both the adults and young during rainy seasons attributed to the parasitic fungus *Sporotrichum globuliferum* Speg., the practice of raising grain year after year on the same areas, as is followed in some parts of the United States, would become altogether unprofitable. Some of this insect's own habits, emphasizing as they do the effects of weather conditions, are among the most potent influences that serve to hold it within bounds by giving its tendency to excessive increase a decidedly spasmodic character.

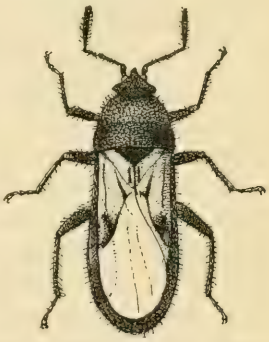

FIG. 1.—The chinch bug (*Blissus leucopterus*): Adult of long-winged form, much enlarged. (Author's illustration.)

[1] *Blissus leucopterus* Say; order Hemiptera, family Lygæidæ.

NOTE.—This bulletin describes the forms and stages of the chinch bug, its habits and natural enemies, and suggests methods of preventing its ravages. It will be of general interest wherever this pest prevails.

DESCRIPTIONS OF THE DIFFERENT STAGES.

THE EGG.

The average length of the chinch bug's egg (fig. 3, *a*, *b*) is three one-hundredths of an inch. In shape it is elongate-oval, the diameter being scarcely one-fifth the length. The top is squarely docked and surmounted with four small, rounded tubercles near the center. When

FIG. 2.—Chinch bug: Adults of short-winged form. Much enlarged. (Author's illustration.)

newly deposited the egg is pale or whitish and translucent, but with age it acquires an amber color and finally shows the red parts of the embryo within, especially the eyes toward the tubercled end. The size increases somewhat after deposition, and the length will sometimes reach nearly four one-hundredths of an inch.

THE LARVAL, OR NYMPHAL, STAGES.

The newly hatched larva, or nymph (fig. 3, *c*, *d*), is pale yellow, with simply an orange stain on the middle of the three larger abdominal joints. The form scarcely differs from that of the mature bug, being but slightly more elongate; but the tarsi have only two joints, and the head is relatively broader and more rounded, while the joints of the body are subequal, the prothoracic joint being but slightly longer than any of the rest. The red color soon pervades the whole body, except the first two abdominal joints, which remain yellowish, and the legs and antennæ, which remain pale.

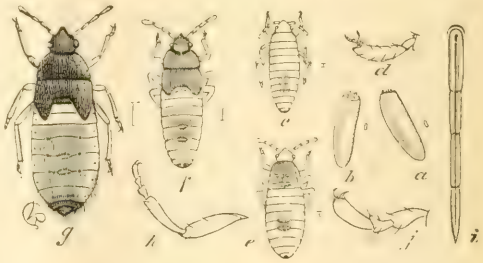

FIG. 3.—The chinch bug: *a*, *b*, Eggs; *c*, newly hatched larva, or nymph; *d*, its tarsus; *e*, larva after first molt; *f*, same after second molt; *g*, last-stage larva; the natural sizes indicated at sides; *h*, enlarged leg of perfect bug; *j*, tarsus of same, still more enlarged; *i*, proboscis or beak, enlarged. (From Riley.)

After the first molt (fig. 3, *e*) the red becomes bright vermilion, contrasting strongly with the pale band across the middle of the

body; the prothoracic joint is relatively longer, and the metathoracic shorter. The head and prothorax are dusky coriaceous; two broad marks on the mesothorax, two smaller ones on the metathorax, two on the fourth and fifth abdominal sutures, and one at the tip of the abdomen, are generally visible, but sometimes obsolete; the third and fourth joints of the antennæ are dusky, but the legs are still pale. After the second molt (fig. 3, *f*) the head and thorax are quite dusky; the abdomen duller red, but the pale transverse band is still distinct; the wing pads become apparent; the members are more dusky; there is a dark-red shade on the fourth and fifth abdominal joints, and ventrally a distinct circular dusky spot covering the last three joints.

In the last-stage larva or nymph (fig. 3, *g*), sometimes called the "pupa," all the coriaceous parts are brown-black, the wing pads extend almost across the two pale abdominal joints, which are now more dingy, while the general color of the abdomen is dingy gray; the body above is slightly pubescent, the members are colored as in the mature bug, the three-jointed tarsus is foreshadowed, and the dark horny spots at the tip of the abdomen, both above and below, are larger.

THE ADULT FORMS.

There are two forms of the fully developed insect, but it is not known that the young of these two forms differ in any respect. One of these forms, the one originally described, is known as the long-winged form and is the only form that occurs over most of the country between the Rocky Mountains and the Allegheny Mountains. This form is illustrated in figure 1.

The second form is much like the first, with the exception of the wings, which are more or less abbreviated, as shown in figure 2. This form occurs along the seacoasts, and in the East extends inland along the lower lakes to northern Illinois. It is not abundant, however, west of a line drawn from Toledo, Ohio, to Pittsburgh, Pa. Throughout the territory in which this short-winged form is found there are also intermingled with them individuals of the long-winged form.

Both of these forms may be described as black, with numerous hairs, also black; the upper wings are whitish, with a black spot on each, and the under wings are white. They are about one-fifth of an inch or less in length and may be easily recognized by the accompanying illustrations (figs, 1, 2, 3, *h*, *i*, *j*).

SEASONAL HISTORY.

Over the territory covered by the long-winged form, as previously given, the insect has two generations each year. The young of the first generation appear in May and June, and those of the second generation in August and perhaps as late as September. The adult

insects (figs. 1, 2) pass the winter among clumps of broom sedge,[1] and where this does not occur in sufficient abundance, among matted grass, fallen leaves, and other rubbish, coming forth from hiding in spring, spreading to the grain fields, where they deposit their eggs, and dying soon afterwards. The young (fig. 3, *c*) hatching from these eggs cluster upon the plants and begin at once to feed upon the juices. Figure 4 illustrates a corn plant with the chinch bugs clustering upon it. The egg-laying season extends over a considerable period, and

FIG. 4.—Corn plant 2 feet tall infested with chinch bugs. (Author's illustration.)

chinch bugs of all ages, sizes, and colors may be found intermingled. By midsummer the majority of the first generation have reached the adult stage, soon after which the eggs are deposited for the second generation, nearly all individuals reaching their full development by late fall or early winter. This second generation develops and matures on corn, millet, kafir, and similar crops.

It must be remembered that each female of the species is capable of laying from 1 to 500 eggs, and she will scatter them during a period

[1] *Andropogon* spp.

of from two to three weeks. The time required for the eggs to hatch is from about ten days to three weeks, and it requires about forty days for the young to become fully developed after hatching from the egg.

In the eastern portion of the country, where the short-winged form (fig. 2) prevails, it is not certain that there is more than a single generation annually. This short-winged form differs very greatly in its habits from the long-winged form, the first passing the winter in the meadows, which it usually attacks in preference to grain fields, whereas during the period known as the Indian summer the developed bugs of the long-winged form (fig. 1) may be observed flying about, evidently searching for winter quarters. With the short-winged form these migrations to and from the places of hibernation are impossible, the insects being totally incapable of flying. A hint of this peculiarity may be witnessed in the case of the exclusively long-winged form of the first generation, for in migrating from one field to another, even though fully half of the individuals may have developed wings ample for flight, they often travel on foot with the young, even going considerable distances from one field to another. If, however, an artificial barrier is interposed in their path, the winged adults appear suddenly to find out that they have another and more efficient mode of travel, and fly over these obstructions.

Throughout the Middle West, then, where this insect does its greatest injury, crops suffer from two attacks annually, although the later one is not always noticed. It must be remembered, however, that, although attracting little or no attention, this later attack is of the utmost importance, for if there are but few of the second generation developing to adults, there can be no serious outbreak the following spring. If, on the other hand, there are enormous numbers of adults developing in the fall and going into winter quarters, there is a probability that, with weather during spring favorable for their development, there will be an excessive abundance the following year.

HIBERNATION.

While the matter of winter quarters has been previously mentioned in a general way, the winter habit of the pest is of such importance that this phase of its life history is deserving of full explanation. Again and again serious destructive outbreaks of the pest in wheat fields have been traced directly to the influence of shocks of corn fodder allowed to stand in the fields throughout the winter. The chinch bugs which flocked to these corn shocks the previous autumn, suitable quarters not being available elsewhere, were thus protected throughout the winter, migrated from the shocks in the spring, and spread over the wheat field. In other cases destructive out-

breaks have been traced directly to woodlands bordering upon the fields (see fig. 5), the chinch bugs beginning their destruction along the margins of the fields nearest to the woodlands, having passed the winter among the fallen leaves or among such clumps of broom sedge as had grown up among the trees and brush. So, too, have destructive outbreaks in the Middle West been traced to the matted grass and fallen leaves bordering hedges of Osage orange by roadsides and elsewhere. The farmer must understand that it is to such places as these that the chinch bugs flock in the fall, and whatever measures he can apply to prevent them from wintering about his fields will be

FIG. 5.—A road between two farms, with neglected hedges on either side affording ample protection for destructive insects during winter. (Author's illustration.)

just so much protection to his crop from attacks of their offspring during the following year.

In the timothy meadows of New England, New York, and northern Ohio these conditions are of less importance, because there the insects pass the winter largely in the meadows and can not migrate to or from these places, except on foot.

Chinch bugs will stand almost any degree of cold, provided it is continuous and they are fairly well protected from sudden changes. And the farmer may be able to take advantage of their hibernation to deal disastrous blows against their occurrence in his fields during the following spring and early summer.

FOOD PLANTS.

Over the western country the major portion of the damage is to grain fields, including corn and also such forage crops as millet, Hungarian grass, and the nonsaccharin sorghums, the outbreak generally originating in wheat, rye, or barley fields and the bugs migrating at harvest to the cornfields. In the eastern part of the country, where the timothy meadows are the most seriously infested, this is not the case, and here the migrations are as likely, or even more so, to be to the timothy meadows as to the fields of corn where both are equally within reach. Oats are not liable to infestation. The chinch bugs attack sugar cane in Mexico, according to Mr. Albert Koebele. They are known to attack the following grasses: Forked beard-grass,[1] broom beard-grass,[2] oat-grass,[3] bur-grass,[4] millet, witch grass,[5] barnyard grass,[6] *Phragmites* sp. ?, sorghum, kafir, large crab-grass,[7] timothy, yellow foxtail,[8] green foxtail grass,[9] Bermuda grass,[10] and what is locally known in Florida as St. Augustine grass. Prof. Lawrence Bruner has also found it feeding upon so-called buckwheat.[11]

It will thus be seen that the insect has an ample food supply outside of the cultivated fields.

LOSSES CAUSED BY CHINCH BUGS.

It would appear that this pest first made its presence known by its ravages in the wheat fields of North Carolina farmers; for we are told that "in 1785 the fields were so overrun with them as to threaten a total destruction of the grain. * * * And at length the crops were so destroyed in some districts that they (the farmers) were obliged to wholly abandon the sowing of wheat. It was four or five years that they continued so numerous, at this time."[12]

In the year 1809, as stated by Mr. J. W. Jefferys[13] the chinch bug again became destructive in North Carolina to such an extent that in Orange County farmers were obliged to suspend the sowing of wheat for two years. In 1839[14] the pest again became destructive

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[1] *Andropogon furcatus.*
[2] *Andropogon scoparius.*
[3] *Arrhenatherum sp.*
[4] *Cenchrus tribuloides.*
[5] *Panicum capillare.*
[6] *Panicum crus-galli.*
[7] *Syntherisma sanguinalis.*
[8] *Ixophorus glaucus.*
[9] *Ixophorus viridis.*
[10] *Capriola dactylon.*
[11] *Polygonum dumetorum or P. convolvulus.*
[12] Webster, Noah. A brief history of epidemic and pestilential diseases, v. 1, p. 279. Hartford, 1799. Quoted in Fitch, Asa. [First] Report on the Noxious, Beneficial, and other Insects of the State of New York, p. 279. Albany, 1855.
[13] Jeffreys, J. W. Chinch bug. *In* The Cultivator, Albany, v. 6, no. 12, p. 200–201, Dec., 1839.
[14] Gibbes, W. S. The season, crops and insects in South-Carolina. *In* The Cultivator, Albany, v. 6, no. 6, p. 103–104, August, 1839.

in the Carolinas and in Virginia, where the bugs migrated from the wheat fields at harvest to the corn, and in 1840 there was a similar outbreak, and both wheat and corn were seriously injured. In all of these cases, however, there is no recorded estimate of the actual financial losses resulting from the attacks of the chinch bug. According to Le Baron during the years from 1845 to 1850 the insect ravaged Illinois and portions of Indiana and Wisconsin, and in 1854 and 1855 it again worked serious injury in northern Illinois. The writer's earliest recollection of the chinch bug and its ravages in the grain fields of the settlers on the prairies dates from this last outbreak. Mr. B. D. Walsh estimated the loss to the farmers of Illinois in 1850 at $4,000,000, or $4.70 to every man, woman, and child living in the State.

In 1863, 1864, and 1865 the insect was again destructive in Illinois and other Western States, its ravages being especially severe in 1864, when we have another attempt at computation of the financial loss. Dr. Henry Shimer, of Mount Carroll, Ill., who had carefully studied the chinch bug, estimated that "three-fourths of the wheat and one-half of the corn crop were destroyed by the pest throughout many extensive districts, comprising almost the entire Northwest." In criticizing the doctor regarding another point, Walsh and Riley[1] admit that the estimate was "a reasonable one," and, taking it as a basis, with the actual cash price per bushel, computed the loss at about 30,000,000 bushels of wheat and 138,000,000 bushels of corn, with a total value of both amounting to over $73,000,000. Of course all computations of this sort are necessarily only approximately correct, but there is more likelihood of an underestimate than of an overestimate in this case.

There was a serious outbreak of the chinch bug in the West in the year 1868, and again in 1871, but in 1874 the ravages were both widespread and enormous. Le Baron computed the loss in 1871 in seven States, viz, Iowa, Missouri, Illinois, Kansas, Nebraska, Wisconsin, and Indiana, at $30,000,000.[2] Riley computed the loss in Missouri alone in the year 1874 at $19,000,000, and added the statement that for the area covered by Le Baron's estimates in 1871 the loss in 1874 might safely be put down as double, or upward of $60,000,000.[3] Dr. Cyrus Thomas, however, estimated the loss to the whole country for the same year at upward of $100,000,000.[4]

The next serious outbreak of the chinch bug of which we have an estimate of the losses occurred in 1887 and covered more or less

[1] Walsh, B. D., and Riley, C. V., editors. Amount of damage done by the chinch bug. *In* Amer. Ent., v. 1, no. 10, p. 197, June, 1869.

[2] Le Baron, William, First Annual Report on the Noxious Insects of the State of Illinois, p. 144. Springfield, Ill., 1871.

[3] Riley, C. V. Seventh Annual Report on the Noxious, Beneficial and other Insects of the State of Missouri, p. 24–26. Jefferson City, Mo., 1875.

[4] Thomas, Cyrus. The chinch bug. U. S. Ent. Com., Bul. 5, p. 7, 1879.

territory in the States of Kentucky, Ohio, Indiana, Illinois, Wisconsin, Minnesota, Iowa, Missouri, and Kansas. In this case the damage was estimated by the United States statistician, Mr. J. R. Dodge, at $60,000,000, the heaviest losses occurring in Illinois, Iowa, Missouri, and Kansas.[1] This gives us as the estimated loss in the 38 years from 1850 to 1887, both inclusive, the enormous sum of $267,000,000.

There was a serious outbreak in Kansas, Iowa, Minnesota, and Illinois, having its beginning probably as early as 1892, but reaching its maximum severity, as in Ohio, in 1896. The loss in Ohio during the years 1894, 1895, 1896, and 1897 could not have fallen far short

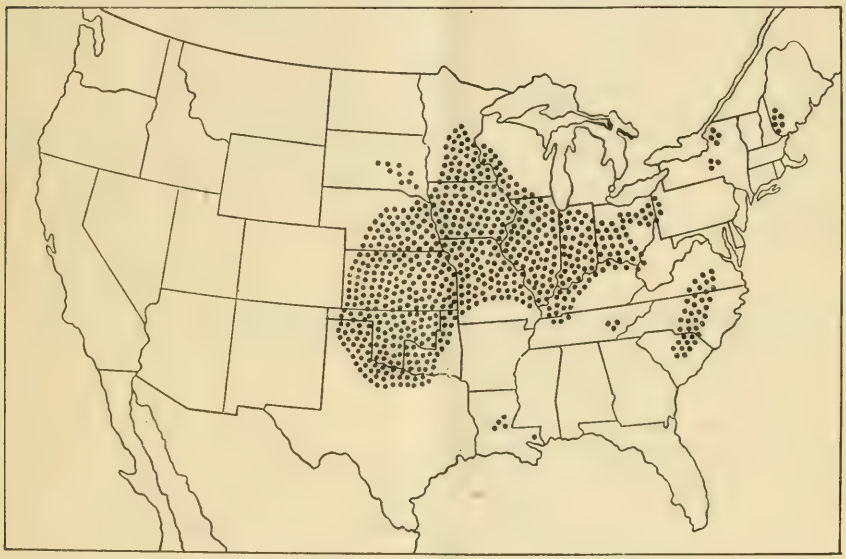

FIG. 6.—Areas in the United States over which the chinch bug occurs in most destructive numbers. (Author's illustration.)

of $2,000,000. If we could have careful estimates of the loss during the last fifteen or twenty years it would in all probability swell the amount to considerably in excess of $350,000,000 for the period from 1850 to 1915. (See map, fig. 6.)

NATURAL ENEMIES OF THE CHINCH BUG.

Chinch bugs have few predaceous insect enemies, none of which, owing perhaps to their repugnant odor, appears to be of any very great importance when it comes to suppressing a serious invasion. They are far more fortunate than most insects in escaping the attacks of natural enemies that exert a tremendous influence in holding other species in check.

[1] Report U. S. Commissioner of Agriculture for 1887, p. 56. Washington, 1888.

THE BOBWHITE OR QUAIL.

Inland the common "quail" or bobwhite is the only bird that can be said to devour the chinch bug in considerable numbers. It is said that from 300 to 400 chinch bugs have been found in the crops of bobwhites; 100, however, is the largest number found so far by the Biological Survey. As the bobwhite is one of our most highly prized game birds, it is slaughtered annually in tremendous numbers, frequently with no object except sport. Some also are killed by flying against electric wires, while during severe winters entire coveys are sometimes smothered or frozen under the snow. As a result the helpfulness of the quail against chinch bugs is greatly diminished. It would seem that as important an enemy of the chinch bug as this bird is known to be would receive protective immunity throughout the agricultural regions and that farmers would see to it that protective laws were not only enacted but also stringently enforced.

The following list will show the degree of protection offered the quail by legislative enactment in the States where the chinch bug is the most destructive (see map, fig. 6). The closed seasons for quail in the several States, during which killing is prohibited by law, are as follows:[1]

Maine, all the year.
New York, protected until Oct. 1, 1918. (Long Island, Jan. 1 to Nov. 1.)
Pennsylvania, December 16 to November 1.
Ohio, protected until November 15, 1915.
Indiana, December 21 to November 10.
Illinois, December 10 to November 11.
Minnesota, December 1 to October 1.
Iowa, December 15 to November 1.
Missouri, January 1 to December 1.
Nebraska, November 16 to November 1 (open season for 15 days only).
Kansas, protected until March 19, 1918.
Oklahoma, February 1 to November 15.
Texas, February 1 to November 1.

The breeding season from latitude 38° northward to Canada begins in May and continues through July and occasionally into September.

OTHER BIRD ENEMIES.

To what extent the birds of the coast region feed upon the chinch bug it is impossible to say. However, among the bird enemies of the pest are the prairie chicken, redwinged blackbird, catbird, brown thrush or thrasher, meadowlark, house wren, tree swallow, horned lark, Arkansas kingbird, Traill's flycatcher, seaside sparrow, savanna sparrow, song sparrow, tree sparrow, and barn swallow.

[1] Palmer, T. S., Bancroft, W. F., and Earnshaw, Frank L., Game Laws for 1914. U. S. Dept. Agr., Farmers' Bul. 628, p. 14-26, Oct. 20, 1914.

THE FROG.

Dr. Cyrus Thomas quotes Ross and others as stating that the common frog is an enemy of the chinch bug. While this is probably true, it is nevertheless well known that comparatively few frogs frequent grain fields, as a rule, and thus the benefit derived from their attacks is of too little importance to merit further notice.

INSECT ENEMIES.

Of the invertebrate enemies of the chinch bug the same may be said as of the frog. The writer has occasionally found a chinch bug containing a species of Mermis, or "hair snake." Occasionally, also, ants may be seen dragging these bugs away, while lady-beetles have sometimes been found to devour them, as recorded by Walsh and Forbes. Perhaps the worst insect enemies of the chinch bug are to be found among its comparatively near relatives—the insidious flower bug,[1] and *Milyas cinctus* Fab., the latter being reported by Thomas as the most efficient of the insect enemies of this pest, while Riley found that the former also attacked it. Prof. Forbes ascertained, by examinations of the contents of the stomach of a ground beetle,[2] that one-fifth of the total food of this species was composed of chinch bugs. Shimer and Walsh both claim that lacewing flies[3] destroy chinch bugs, and they are doubtless correct. The writer has very often found dead chinch bugs entangled in spider webs, although whether killed for food or by accident it has been impossible to determine.

A minute hymenopterous or wasplike parasite of the egg has recently been discovered in Kansas by Mr. J. W. McCulloch of the Kansas Agricultural Experiment Station, but little is as yet known regarding its efficiency as a means of control.

NATURAL CHECKS OTHER THAN ANIMALS.

WEATHER CONDITIONS.

There are two natural checks to the increase of the chinch bug other than animal enemies. One of these is vegetable in nature, being a fungus, the other meteorological, and the interrelation of the two is so close that the former is almost entirely dependent upon the latter. It will at once be seen that the chinch bug, occurring as it does from but little north of the equator to a latitude of nearly 50° north, and from an elevation of more than 200 feet below sea level in the Imperial Valley of southern California to upwards of 6,000 feet above sea level in the mountainous regions, must be able to withstand almost every conceivable variation of climatic conditions.

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[1] *Triphleps insidiosus* Say (*Anthocoris pseudo-chinche* of Fitch's Second Report).

[2] *Agonoderus pallipes* Fab.

[3] *Chrysopa* spp.

(See map, fig. 7.) So far as the influence of temperature is concerned, it is only in the most unprotected situations that severe winter weather appears to have much effect in regulating the abundance of the pest, although frequent freezing and thawing is known to be

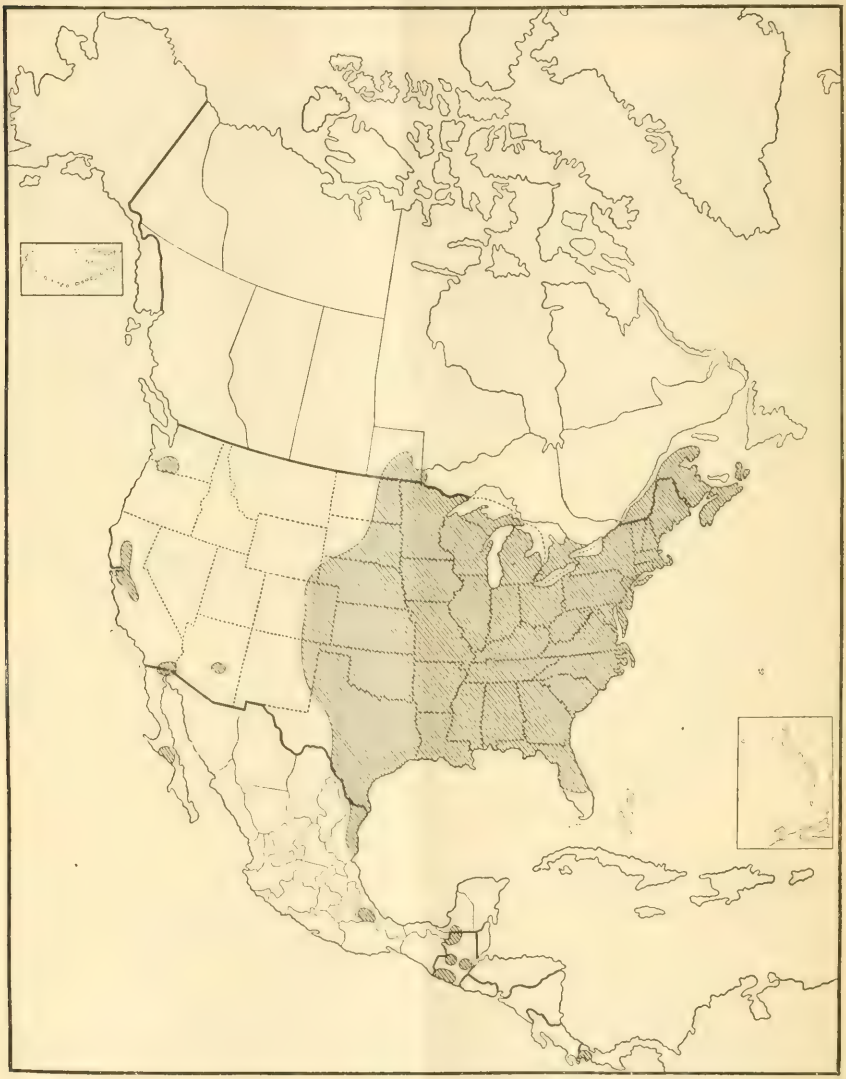

FIG. 7.—Map of North America showing areas infested by chinch bug. (Author's illustration.)

fatal to a large percentage of the adults if these occur in exposed situations. Thus temperature may practically be eliminated from consideration. It is also true that the nearly developed insect will withstand not only the humidity of the Tropics, but continuous drenching rains of more northern latitudes. It is at the time of

hatching that the species is most susceptible to meteorological conditions. Frequent drenching rains during the hatching season are fatal to the pest almost to the extent of extermination, and it is due to this more than to any other influence that the chinch bug is kept within the limits of its present abundance and destructiveness. It matters little how great a number of these insects pass the winter in safety, provided there are sufficiently prolonged, drenching rains during the hatching period. Again, with an excessive abundance of individuals developing from the first generation, if at the time of the hatching of the young of the second generation there are frequent drenching rains, an outbreak the following year is prevented. Thus it is that although an outbreak may seem inevitable as the season for the ravages of the chinch bug draws near, there is often a radical reduction instead of an increase in numbers. The forecasting of chinch-bug outbreaks is therefore based wholly upon the uncertain forecasting, months in advance, of meteorological conditions that are likely to occur at certain periods. If the farmer would but watch the seasons he need not be taken unawares by chinch-bug outbreaks, as dry weather during the two breeding seasons is usually sufficient to precipitate an invasion the following year, providing that, at the critical period, or time of hatching, rains do not destroy the young. The general statement may be made that throughout the Middle West a dry June followed by a dry August is favorable for the development of chinch bugs. These dates will of course vary, and must not be applied to the more southern or more northern localities.

PARASITIC FUNGI.

The fact that the abundance and consequent influence of fungous enemies of the chinch bug are almost entirely dependent upon meteorological conditions is sufficient to place them in a secondary position, even though they may, under favorable weather conditions, act as natural checks.

Dr. Henry Shimer[1] long ago made the truthful and important statement that "this disease among the chinch bugs was associated with the long-continued wet, cloudy, cool weather that prevailed during the greater portion of the period of their development." These are precisely the conditions under which these fungi have been observed to prove the most fatal to the chinch bug during recent years where their introduction among the host insects was accomplished by artificial means. Although Shimer probably never anticipated the artificial cultivation of his "disease" and the results which have since been obtained from its artificial dissemination in the fields, yet his careful and painstaking studies must ever be

[1] Shimer, Henry. Notes on *Micropus* (*Lygarus*) *Leucopterus*, Say ("The Chinch Bug"). With an account of the great epidemic disease of 1865 among insects. *In* Proc. Acad. Nat. Sci. Phila., v. 19, p. 75-80, May, 1867.

associated with the application of fungous diseases in the destruction of insects in America.

The principal fungus to be artificially employed in destroying chinch bugs has come to be known as the chinch-bug fungus [1] and this is the one used by the late Dr. Snow in Kansas for artificial introduction into localities where there was an overabundance of these bugs.

Drs. Roland Thaxter and S. A. Forbes devised a method of artificial cultivation, the latter using a basis of sterilized mixture of beef broth and corn meal. As this fungus has many other host insects, it is probably present to a greater or less degree throughout the country every year. There is no doubt that during wet weather considerable benefit may be derived from the artificial cultivation and application of this fungus, but its efficiency is very dependent upon this meteorological condition, and, as has already been shown, chinch bugs develop in the greatest abundance in dry seasons. It will thus be seen that only during unusual seasons—that is to say, seasons that have been dry while the chinch bugs were hatching from the eggs but wet afterwards—can satisfactory results be expected from this measure.

The effects of this fungus have probably been overestimated, although there is no doubt whatever that those who have been most instrumental in popularizing this means of destroying chinch bugs were thoroughly sincere and honest in their statements. One very important element of deception to the ordinary farmer, when assuming the results of the effect of this fungus, lies in the fact that chinch bugs, when molting for the last time and passing from the last-stage larva to the adult, hide away under the sheaths of corn and other grain, and, casting the larval skin, make their escape, leaving this behind. These cast skins will occur in immense numbers in such places and frequently become covered with a white mold. It is almost impossible for anyone except an expert to distinguish the difference between chinch bugs that have been actually killed by this fnugus and the mass of cast skins covered with ordinary mold. The uncertainty as to the effects of this fungus is responsible for the fact that it has fallen largely into disuse during recent years. It will thus be seen that this whole matter hinges upon meteorological conditions which are, as has been stated, most powerful factors in holding the chinch bug continually in check, and it is following a succession of dry seasons that the pest commences to become destructive. During seasons of excessive abundance of chinch bugs this fungus will almost invariably appear among them in the fields, provided that at this time there occurs a considerable period of wet weather. Up to the present time absolute proof has not been

[1] *Sporotrichum globuliferum* Speg.

obtained that this fungus attacks and kills otherwise healthy individuals or that fatalities are not confined to spent females or those of both sexes that have become physically weakened by other causes.

REMEDIAL AND PREVENTIVE MEASURES.

All remedial and preventive measures that have been found to possess the merit of reasonable efficiency and practicability are discussed in the following pages. These may not all prove applicable in all localities or under every variety of circumstance, and the farmer will often have to adapt his protective measures to weather conditions, location of field and its surroundings, and to the thousand and one other variations of a similar nature.

DESTRUCTION OF CHINCH BUGS WHILE IN HIBERNATION.

The first effort that may be made with a view to warding off an attack of chinch bugs is to destroy them in their winter quarters. This can be accomplished by burning all dried grass, especially such as grows in clumps, notably broom sedge or sage grass, leaves, or other rubbish during winter or early spring, especially during early winter. The burning of such will destroy thousands of bugs in their winter quarters; but sometimes the matted bluegrass remains green in winter, or the weather is not sufficiently dry to enable the farmer to burn over such places. In such cases a flock of sheep, if given the freedom of the fields during winter and spring, will eat off all living vegetation and trample the ground with their small feet, so that not only is all protective covering for the bugs removed, but also the bugs are crushed. So it is with the matted grass along roadsides and fences, especially the Virginia worm rail fence (fig. 8). The greater ease with which the narrow strip of grassland along a post-and-wire fence can be kept free of matted grass and leaves, as compared with that along a hedge or rail fence, indicates that there may be an entomological factor connected with the modern farm fence that has been overlooked, giving it, in this respect, an advantage over the more ancient form.

A good illustration of the fact that large numbers of chinch bugs may be in hiding among fallen leaves in woods and other places and escape detection is furnished by a collection, made late in April, of a quantity of dried leaves from about a vineyard located on a narrow neck of land about one-fourth of a mile from the Bay of Sandusky on the one side, and about one and one-half miles from the shore of Lake Erie on the opposite side. At the time of collecting the leaves only an occasional chinch bug was to be observed, but under a warm atmosphere they began to bestir themselves and soon demonstrated that there had been a large number ensconced unseen among the dried and curled dead grape leaves.

Shocks of fodder corn left in the fields over winter certainly afford protection for many chinch bugs, as will also coarse stable manure spread on the fields before the chinch bugs have selected their place of hibernation in the fall. In short, the first protective measure to be carried out is a general cleaning up in winter or early spring, either by burning, or pasturing, or both.

SOWING DECOY PLATS OF ATTRACTIVE GRAINS OR GRASSES IN EARLY SPRING.

Judging from the manner in which the overwintered adults are attracted to hills of young corn, wheat fields, or plats of panic and foxtail grasses, it has always seemed to the writer practicable to take

FIG. 8.—Poorly kept roadside with rail fence overgrown with brambles, thus affording protection for large numbers of destructive insects during winter. (Author's illustration.)

advantage of this habit and sow small patches of millet, Hungarian grass, spring wheat, or even corn, early in the spring and thus bait the adults as they come forth from their places of hibernation. Their instincts will prompt them to seek out the places likely to afford the most desirable food supply for their progeny, and if an artificial supply can be offered them that will be more attractive than that furnished by nature, the bugs will certainly not overlook the fact, but will take advantage of it to congregate and deposit their eggs there, whereupon eggs, young, and adults can be summarily dealt with a little later by plowing both bugs and their food under and harrowing and rolling the ground to keep the former from crawling to the surface and escaping.

The writer has thoroughly tested this method in a case where the bugs, young and old, had taken possession of a plat of neglected ground overrun with panic grass which was mown and promptly removed and the ground plowed, harrowed, and rolled before the bugs could escape, thus burying them beneath several inches of soil, out of which they were unable to make their way. As a consequence they were almost totally annihilated, hardly 1 per cent making their escape to an adjoining cornfield.

WATCHFULNESS DURING PROTRACTED PERIODS OF DROUGHT.

It has always appeared to the writer as though a little watchfulness on the part of farmers during periods of drought might enable them to determine whether or not chinch bugs were present in any considerable numbers in their fields in time to interpose a strip of millet between the wheat and corn, to be utilized later as previously indicated. Instances have come under observation where, in wheat fields overgrown with panic grass and meadow foxtail, the bugs transferred their attention to these grasses as soon as the wheat was harvested. In such cases a prompt plowing of the ground would have placed the depredators beyond the possibility of doing any serious injury. If the weather at the time is hot and dry, a mower may be run over the stubble fields or along the borders, cutting off grass, weeds, and stubble, as the case may be, leaving them to dry in the hot sun, when, in a few hours, they will burn sufficiently to roast all bugs among them, and, while not destroying every individual, this will reduce their numbers to such an extent that they will be unable to work any serious injury.

DIFFICULTY OF REACHING CHINCH BUGS IN MEADOWS.

There is, however, some doubt in regard to the practicability of applying these measures in timothy meadows. Meadow lands can be burned over with perfect safety to either the grass or clover, if done while the ground is frozen, but there is danger of injury if burned over in spring, and it is somewhat doubtful if the hibernating chinch bugs would be killed unless the surface of the ground was heated to a degree that the grass and clover plants would hardly be able to withstand.

Infested areas of meadow land could be plowed, it is true, but the work would have to be done very carefully, else the grass and stubble would be left to protrude above ground along each furrow and constitute so many ladders by which the chinch bugs could easily crawl out and make their escape. Where the ground will admit of subsoiling, or where a "jointer" plow can be used, this latter difficulty can be easily overcome. Usually, however, the chinch bugs work too irregularly in a field to permit of plowing under infested areas

without disfiguring the field too much for practical purposes, especially in the case of meadows, unless it be where the bugs have migrated en masse from an adjoining field, when a narrow strip along the border can often be sacrificed to good advantage. In many instances the drastic measure of turning under a few outer rows of corn with the plow would have saved as many acres from destruction. In the majority of cases it is the fault of the farmer himself that these measures are not effective, as he will seldom take the trouble to burn the dead leaves, grass, and trash about his premises at the proper time, and when there occurs an invasion of chinch bugs, instead of resorting to heroic and energetic measures to conquer them on a small area, he usually hesitates and delays in order to determine whether or not the attack is to be a serious one, and by the time he has decided which it is to be the matter has gone too far and the chinch bugs have taken possession of his field. This is especially true in the West, where the bugs breed exclusively in the fields of wheat, rye, and barley, often remaining unobserved until harvest, when they suddenly and without warning precipitate themselves upon the growing corn in adjacent fields. In fighting the chinch bug, promptness of action is about as necessary as it is in fighting fire.

ELIMINATING CHINCH BUGS FROM TIMOTHY MEADOWS BY CROP ROTATION.

In several instances where chinch bugs have become especially destructive to timothy meadows over considerable areas of country, it has been found that these outbreaks were attributable to the fact that these sections of country were largely given over to dairying. The dairymen and stockmen found it more desirable to allow timothy pastures and meadows to remain more or less permanent, with the result that the chinch bugs gradually became so excessively abundant as to destroy the grasses on these areas. In a number of instances it was found that where the prevailing agricultural methods were changed and the infested grasslands were broken up and devoted to other crops, the difficulty was eliminated, as the new meadows were not attacked. This shows that throughout the country where the short-winged chinch bug attacks timothy meadows a rotation of crops will be found an efficient measure in overcoming the difficulty with a reasonable degree of permanency.

UTILITY OF KEROSENE IN FIGHTING CHINCH BUGS.

In fighting the chinch bugs there is at present no more useful substance than kerosene, either in the form of an emulsion or undiluted. From its penetrating nature, prompt action, and fatal effects on the chinch bug, even when applied as an emulsion, it becomes an inexpensive insecticide, while it has the further advantage of being an article universally found in every farmhouse, and is therefore always

at hand for immediate use. The emulsion has the further advantage that it can be reduced sufficiently in strength to preclude injury to the vegetation and still be strong enough to be fatal to insect life.

Diluted and ready for use, the emulsion is prepared as follows: Dissolve one-half pound of hard soap in 1 gallon of water, preferably rain water, heated to the boiling point over a brisk fire, and pour this suds while still hot into 2 gallons of kerosene. Churn or otherwise agitate this mixture for a few minutes until it becomes of a creamlike consistency and, on cooling, forms a jellylike mass which adheres to the surface of glass without oiliness. For each gallon of this emulsion use 15 gallons of water, mixing thoroughly. If applied to growing corn, it will be best to use the emulsion either during the morning or evening, say before 8 a. m. or after 5 p. m., as at these times it will be less likely to affect the plants than if applied in the heat of the day. The great drawback in its use is that if not properly made it will prove as destructive to the corn as the bugs.

Where an invasion of the chinch bug is in progress from a field of wheat to an adjoining field of corn, as an illustration, the marginal rows of corn can be frequently saved, even after the bugs have massed upon the plants, by spraying or sprinkling them freely with kerosene emulsion, being careful not to get much of it directly into the crown of the plants, and using a sufficient quantity so that the emulsion will run down the outside and reach such bugs as are about the base of the plants. This treatment will kill the bugs clustered upon the corn, and while it will not keep out those on the way to the field, it will cause a halt in the invasion, and thus give the farmer an opportunity to put other measures in operation, one of which will include the use of kerosene in another manner. In cases where the young bugs have already taken possession of one or two border rows of corn and quick action is required on the part of the farmer in stopping their advance, the drenching of the corn plants by a strong soap suds, 1 pound of soap dissolved in 4 gallons of water, may be of service. If a deep furrow is plowed along the edge of the field (fig. 9), running the land side of the plow toward the field to be protected, the furrow will form a temporary barrier to the incoming hordes.

UTILITY OF DEEPLY PLOWED FURROWS SUPPLEMENTED BY THE USE OF KEROSENE EMULSION.

In dry weather the sides of the furrow can be made so steep and the soil so finely pulverized that when the chinch bugs attempt to crawl up out of the furrow they will continually roll back to the bottom. In case of showery weather, which prevents the sides of the furrow from remaining loose and dry, the bottom can be cleared out with a shovel, making it more smooth and the side more perpendicular, thus rendering it so much easier for the bugs to follow along the bottom than to

attempt to climb the sides. If holes are dug across the bottom at distances of, say, 30 or 40 feet, the bugs will fall into them and can be still more easily disposed of by the use of kerosene. That both of these measures are thoroughly practicable the writer can attest by ample personal experience, and he knows that under most conditions that are likely to obtain prompt and efficient application is all that is necessary. During showery weather the tar line is far preferable to the furrow, but in excessively dry, windy weather the dust will adhere to the tar and encrust the surface so that the bugs can soon easily

FIG. 9.—The two operations in the preparation of chinch-bug barriers; one, the plowing of the furrow; and the other, the dragging of a log or other heavy cylindrical object of the proper size back and forth in the furrow to keep the soil pulverized and prevent the bugs from making their way out of the sand. (Original.)

walk across. This is a case where a farmer must use his own judgment. During a few days this work will demand the closest watching and application, but fields of corn can be protected thoroughly and effectually if these measures are faithfully carried out, and the expense of time and money will be found to be less than in almost any other plan that has been discovered up to this time. In no case has a field attacked by a migrating army of chinch bugs come under the writer's observation that could not have been saved from very serious injury by the prompt use of either of these measures, although

under some conditions the farmer might find it advantageous to apply some of the other methods of protection here given. In all of the following methods crude petroleum or road oil may be substituted for coal tar if the former is more easily obtainable.

THE SURFACE AND COAL-TAR OR ROAD-OIL METHOD.

The objections made by farmers to the use of most of these barriers is that the most finely pulverized soil soon becomes incrusted by even the slightest rainfall and the bugs then pass over it without difficulty, while barriers of boards are expensive. It is feasible to eliminate both by simply smoothing off a path along the margin of an infested field where such an one adjoins the one to be protected. This can be done with a sharp hoe, and as the margins of wheat fields usually become compacted, it is but little trouble thus to clear off a path a foot or more in width, smooth as a floor, with the surface almost as hard. Along this path circular post holes are sunk, as in the bottom of furrows, and a train of coal tar is run between them, being so arranged that it will reach the post hole at the edge farthest from the field from which the bugs are migrating. The bugs, on reaching the train of tar or oil, will follow along until they reach the post hole, while those meeting with the post hole will usually divide and, following around it, join with the flow of bugs moving along the barrier. The result is that they become congested in the acute angle where this barrier is intercepted by the post holes. Those in the apex of this angle can not turn back, and thus are continually pushed into the post holes by those behind. As the bugs, varying from the red larvæ of the younger stages to the almost black ones of the last stage, mass along the line of coal tar, they have much the appearance of a reddish-brown stream running into the holes. From these holes there is no escape and here the bugs can readily be killed by sprinkling with kerosene. The slightest train of coal tar is sufficient to obstruct the passage of the bugs, and light rains will not affect its efficiency.

In dry weather these trains of tar or oil, as the case may be, soon become covered over with dust and must be renewed; but in showery weather there is no dust, and if the coal tar is renewed daily or, at most, twice each day, it will accomplish its work and nothing further will be needed than to kill the bugs that have collected in the post holes. This measure is inexpensive and can be promptly put into operation if the coal tar is at hand. The writer has been able in this way effectively to protect a field of corn bordered on two sides by a wheat field literally overrun with chinch bugs at harvest and during a time when light showers were occurring, frequently several times each day.

THE RIDGE AND COAL-TAR METHOD.

Differing quite materially from the preceding are the various combinations of coal tar or road oil and ridges of earth, smoothed and packed along the apex, or, instead of the ridge of earth, 6-inch boards, such as are ordinarily used for fencing, placed on edge and the upper edge coated with tar.

Prof. Forbes has reported excellent results from the application of a line of coal tar put directly upon the bare ground where the surface has been rendered compact by a recent fall of rain. Even in this series of protective measures kerosene can be used to great advantage. In the experiment recorded by Forbes the coal tar was put upon the ground between a wheat field and a cornfield from an ordinary garden sprinkling pot from which the sprinkler had been removed and the orifice of the spout reduced in size with a plug of wood until the tar came out in a stream about the size of the little finger and made a line on the surface of the ground about three-fourths of an inch in width. Post holes were sunk along the line from 10 to 20 feet apart on the side next to the wheat field, thus practically completing the barrier, and the chinch bugs, being unable to cross the line of tar, accumulated in the post holes in vast numbers, where they were killed, and those bugs that had already entered the cornfield before the barrier was constructed were prevented from spreading farther by tar lines between the rows of corn, the infested corn itself being cleared of bugs by the application of kerosene emulsion. The same writer [1] states that several farmers in Vermilion County, Ill., prepared for the coal-tar line by hitching a team to a heavy plank and running this, weighted down with three or four men, over the ground once or twice until a smooth, hard surface had thus been made to receive the tar. If the barrier was to be made in sod, a furrow was plowed and the bottom of this made smooth by dragging the plank along the bottom. In both cases post holes were sunk along the tar lines, and in these were placed cans or jars into which the bugs fell in myriads and were destroyed.

On one farm of 250 acres a coal-tar line 90 rods in length was renewed once each day and killed about 8 gallons of chinch bugs. In the case of another farmer there were 300 rods of tar lines with post-holes, cans, etc., which resulted in destroying about 10 bushels of chinch bugs. A 6-gallon jarful was destroyed in less than half a day at one point on the line. In this last instance the lines of tar were renewed three times a day, but even then less than a barrel of tar was used. Still another farmer, with 120 rods of tar line, used about a third of a barrel of tar and did not lose a hill of corn; he caught

[1] Forbes, S. A. Twentieth Report of the State Entomologist on the Noxious and Beneficial Insects of the State of Illinois. Ninth Report of S. A. Forbes for the years 1895 and 1896, p. 39–40, Springfield, Ill., 1896.

chinch bugs by the bushel. In some of the cases cited the tar line was run in a zigzag course, the postholes being situated at the angles, and in others leader tar lines were run obliquely to the main tar line, one end terminating at the traphole, but both of these plans were afterwards regarded as unnecessary, a single straight line being entirely sufficient and less expensive. The numerous cases where these methods were put into execution with entire success and at small expense afford the best possible proof of their practical utility. If a farmer is situated near town, where refuse tin cans are dumped in any locality where they can be got out of the way, he can select the larger of these, set them in the postholes, and partly fill them with kerosene and water. The water, being heavier than the kerosene, will sink to the bottom, leaving a stratum of kerosene on the surface. The chinch bugs falling into this will be forced down by the weight of those coming after, and thus all will be passed through the kerosene into the water below. This will obviate the necessity of frequently emptying the cans or treating their contents. It may also be stated that where the postholes are quite deep and enlarge at the bottom the bugs falling into them will perish without further attention.

OTHER BARRIER METHODS.

The late Dr. Snow, working in Kansas, followed a somewhat different method, and one that, under certain conditions, might be found superior to that used by Prof. Forbes, or the furrow and kerosene method applied by the writer in Ohio. This modification consists in throwing up a double furrow, known among farmers as "back furrowing," thus forming a ridge the top of which is smoothed and packed with a drag having a concave bottom of the form of the ridge to be made. If the bottom of this drag is covered with zinc it will be found to keep bright and polished, and by this means make a smoother ridge. Along the top of this ridge is run a train of coal tar as it came from the gas works, or crude petroleum as taken from the oil wells. The former is more easily obtained, except in certain localities, and will probably be found the more practical, as it stands on the surface better and is not so readily washed away by rains. Both of these substances are, however, offensive to the bugs, and they will seldom attempt to cross them or even come close enough to touch them, but on approach will turn and run along the ridge in the evident hope of finding a gap through which they can pass. Postholes were dug on the outside of the line, but close up to it, so that the bugs in passing along beside the tar line would crowd each other into them. Dr. Snow suggested that it is best to construct this barrier several weeks prior to the time when it will be needed, as then the tar line has but to be run along the ridge and the postholes dug, when

the whole system is complete, and the chinch bugs can be thus shut out from the first.[1]

With these barriers of either ridge or furrow and the use of coal tar or crude petroleum, supplemented by kerosene emulsion, a very large percentage of the injury from chinch bugs may be obviated, and, in fact, with a reasonable degree of watchfulness and prompt action all injury from migrating hordes may be prevented. The use of tarred boards set on edge or slightly reclining might, under some circumstances, take the place of the ridge or furrow, but these cases will be exceptional, and the use of kerosene emulsion will probably be found equally practicable here, as also will the post holes for collecting the chinch bugs. This method is merely cited in order to call attention to its possible use where the others are found impracticable.

THE USE OF FURROWS WITHOUT PETROLEUM OR COAL TAR.

The plowing of furrows (fig. 9) has been in vogue since the first writings of Le Baron and the second report of Fitch, and may be utilized in other ways than those previously mentioned. A heavy log or other cylindrical object of the proper size dragged back and forth in this furrow will pulverize the soil in dry weather, and Dr. Forbes has recorded the fact that where this furrow has a temperature of 110° to 116° F. it is fatal to the young bugs that fall into the furrow, even if they are not killed by the log. As 120° is not uncommon in an exposed furrow on a hot summer day, it will be observed that there may be cases where this method will be found very serviceable, and especially is this likely to prove true in a sandy soil with a southern exposure. In sections of the country where irrigation is practiced, these furrows may be flooded and in this way rendered still more effective without the expenditure of either time or money to keep them in constant repair. Riley long ago laid considerable stress on this measure, believing it of much value, especially in the arid regions of the far West. The same writer advised the flooding of infested fields, wherever it could be done, for a day or so occasionally during the month of May. It is hardly probable, however, that this will often be found feasible except in rice fields, where it is sometimes practiced.

NECESSITY FOR PREVENTING CHINCH BUGS FROM BECOMING ESTABLISHED IN FIELDS OF WHEAT AND GRASS.

In the foregoing it will be observed that prevention of migration has been the chief end in view, either by destroying the chinch bugs in their hibernating quarters, and thus preventing the spring migration to the breeding places, or by various traps and obstructions to prevent them from migrating from such places to others not already

[1] Snow, F. H. Contagious diseases of the chinch bug. Univ. Kans. Exp. Sta. Fifth Ann. Rpt. of the Director for the year 1895, p. 45–47, 1896.

infested. The great problem remaining to be solved is to prevent their breeding in wheat fields at all. As has been shown, it is absolutely impossible with our present inability to forecast the weather months in advance, to be able to foretell whether or not an outbreak of chinch bugs is likely to take place. There may be an abundance of bugs in the fall—enough to cause an outbreak over a wide section of country—and these may overwinter in sufficient numbers to cause some injury in spring, yet a few timely, drenching rains will outbalance all of these factors, and our wisest prognostications fail of proving true. It is this very factor of uncertainty that renders unlikely the successful carrying out, over any large area of country, of any protective measures, where, as in this case, the benefit to be derived will only be realized nearly a year afterwards, if at all. The average farmer, when smarting under a heavy loss, will often take such long-range precautions as to sow belts of flax, hemp, clover, or buckwheat around his wheat fields once; but if the chinch bugs do not appear, and he sees the useless investment of time, labor, and seed, he will be likely to conclude next year to take the risk and do nothing. For the present, then, we have no method whereby we can prevent the chinch bugs from taking up their abode in wheat fields or timothy meadows and raising their enormous families there, except to destroy the adults in their winter quarters.

The writer once tried to destroy the young in a wheat field by spraying with kerosene emulsion the small areas of whitening grain that indicated where the pests were massed in greatest abundance. The result was unsatisfactory, and it is very doubtful if it is possible to apply this measure with any degree of success, and we are forced to the conclusion that, for the present at least, we shall be obliged to rely upon the measures previously given. It therefore becomes of the utmost importance to clean up the roadsides and the ground along fences and patches of woodland, as well as any other places likely to afford protection for the hibernating chinch bugs. There are, of course, obstacles in the way of carrying out this plan generally over any large area of country, and especially in sections where the rail fence predominates. But as the country gets older it will be found that it is not chinch bugs alone that seek these places in which to pass the winter, but myriads of the other insect foes of the farmer as well, and that careful attention to the condition of roadsides, lanes, hedgerows, and waste places about the farms, during the season when insects seek out these places wherein to pass the winter, will pay well for the time expended in that direction. It may come about that some phase of the street-cleaning reform may invade the country, and it is certain that if such were to occur it would, in time, save the country enough to go far toward reducing the expense of securing good roads. In fact, the term "good roads" ought to include

the proper care of the roadsides as well as the grading and macadamizing of the roadbeds.

There are at present so-called "weed laws" in many States, and, though more or less of a dead letter in some cases, these laws are steps in the proper direction. The time when insect pests will be looked upon, in the eye of the law, as so many public nuisances, and the harboring of them a corresponding crime, may be a long way off, but as it gradually draws nearer we shall come to learn that after all it is the rational view to take and will go far toward solving not only the chinch-bug problem, but many others of a similar nature. So far as the chinch bug is concerned, when we burn over the waste lands and accumulated rubbish about our farms in autumn or winter we are simply applying the same check that the dusky savage did when he lighted the prairie fires, though unwittingly and for an entirely different purpose. In the timothy meadows of the northeastern portion of the country where, for lack of wings fitting it for locomotion, the chinch bug does not so largely migrate to the waste lands in autumn, the problem is somewhat different, and it will require some careful experiments to determine the exact effects both on the hibernating chinch bugs and on the grass roots of burning over the meadow lands in winter. There can be little doubt, however, that a rapid rotation of crops, so as not to allow the short-winged form to become thoroughly established in a meadow, and the burning over of waste places, thus destroying such rubbish and débris as will serve to offer hibernating places for the long-winged form, will go far toward settling the chinch-bug problem in grasslands.

As previously stated, the chief drawback in putting preventive measures in force is the difficulty of foretelling an invasion. In northeastern Ohio in 1897 hundreds of acres of timothy meadow were destroyed after the hay crop had been removed, but so late that the farmers did not suspect the true condition of their meadows until the spring of 1898, when the young grass failed to put forth, and an examination revealed the fact that the roots had been killed, the abundance of chinch bugs pointing unerringly to the cause of the trouble, though in many cases a heavy crop of hay had been removed the previous year where now the ground was entirely bare. While in the case just cited a previous knowledge of the presence of chinch bugs in these meadows might not have enabled the owners to have saved them in the fall of 1897, yet fall plowing of the land, possibly early enough to have had the ground sown to fall wheat, would have buried the majority of the bugs so deeply in the soil as to have killed vast numbers of them and thus prevented their migration to other lands in the spring of 1898. A rotation of crops that would have included grass for not to exceed two successive

years, followed by wheat, would have amounted to precisely the same remedial measure as the one suggested.

A case in northeastern Ohio has come to the writer's notice where an infested timothy meadow was plowed late in the fall of 1897. Late in April of 1898 this ground was cultivated, rolled, and harrowed several times and most carefully and completely prepared for corn, which was planted, but with the result that a portion of the field was attacked and destroyed by chinch bugs, largely of the short-winged form. An examination about June 10 revealed the bugs in considerable numbers about the plants still remaining, but scattered over the field were more or less numerous clumps of timothy, in some cases apparently killed by the chinch bugs, while in others the bugs were literally swarming about the dying but still green clumps of grass, thus showing that they had either not been buried by the plowing and cultivation of the ground or else the grass had not been thoroughly covered, and thus ladders had been left whereby the bugs were enabled to climb to the surface.

SUMMARY OF REMEDIAL AND PREVENTIVE MEASURES.

In summing up the matter of remedial and preventive measures for the control of the chinch bug, it may be stated that the insects can be destroyed in their places of hibernation by the use of fire. They can be destroyed while in the act of migrating from one field to another by barriers or deep furrows supplemented by post holes and by burying them under the surface of the ground with the plow and harrow, or the latter method may be applied after the bugs have been massed upon plats of some kind of vegetation for which the bugs are known to have a special fondness, these decoy plats being so arranged as either to attract the females and induce them to oviposit therein or to intercept an invasion from wheat fields into cornfields. When these decoys have been turned under with a plow and the surface immediately smoothed and packed by harrow and roller the bugs will be destroyed, while in the cornfields they can be destroyed on the plants by the application of kerosene emulsion. Without vigilance and prompt action, however, only indifferent results are to be expected from any of these measures.

There are several spraying materials which can be used effectively against the bugs after they have congregated on the young corn, but, unfortunately, most of these are injurious to the plants. Kerosene emulsion of 5 per cent strength will generally kill the bugs and will not always injure the corn. The stock solution is made by boiling 1 pound of good lye soap in 1 gallon of water, adding this to 2 gallons of kerosene, and stirring the mixture with a paddle for 5 to 10 minutes. A better way to stir the mixture is to put the nozzle of the spray in the vessel and pump the liquid back into the vessel for five minutes.

Dilute the mixture to a 4 or 5 per cent solution by adding soft water. Some of the proprietary spraying materials and cattle dips

have been used to kill the bugs where they have become alarmingly abundant. One serious objection to these materials is that they are very often injurious to the plants. However, it is sometimes better to sacrifice the first few rows and save the cornfield than to let the bugs have their way.

DESTRUCTION OF CHINCH BUGS WHILE IN HIBERNATION.

The burning of grasses and rubbish about the farm during winter to destroy hibernating chinch bugs has been often recommended and is doubtless the most effective measure to be taken against future ravages of the pest.

In the Southwest the chinch bugs are known to congregate in bunches of grass in late October and remain there till the warm days of early spring. It is only a matter of burning off these grasses at the proper time effectually to rid such places of the pest, and the grasses are generally sufficiently dry to burn readily by the first of of November. The chinch bugs crawl deep down among the grass stems, a few of them even getting beneath the dust and débris, thus seeking protection from the freezes that are to come. It is very important that the grass be dry and yet burn slowly, so that the heat will thoroughly penetrate the dense grass and reach the bugs. It is not necessary for the fire to come into direct contact with the bugs in order to kill them, as they died very quickly in the laboratory when exposed to the heat of a flame from 12 to 20 inches distant, the fatal temperature being in these experiments about 111° F. Fall burning of the grasses among which the bugs are congregated has a twofold value—first, it will kill large numbers of bugs directly; and, second, the bugs not killed by the fire will be left exposed to the winter freezes, which of themselves will in ordinary seasons kill many of them. On several occasions during fall and spring bugs were removed from the stubs of burned grass and the percentage of dead and live bugs obtained. On an average about 75 per cent were killed in the fall and about 63 per cent in the spring. In the spring about 20 per cent of the bugs which hibernated in the clumps of grasses were dead from exposure and other causes. From natural causes and burning in spring about 83 per cent of the bugs were dead. These percentages were obtained by actual count of the insects and are not from estimates. The fire can not reach all the bugs, even with the most careful burning, because of protection afforded by green or wet stems in early fall and late spring; therefore it is essential that the grass be burned during late fall or early winter. While this remedy is recommended above all others, its effectiveness is entirely dependent upon the farmers and their cooperation, but it is an easy matter for neighborhoods to combine in an effort to fight the pest in this manner.

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

COCKROACHES.

By C. L. MARLATT,
Entomologist and Acting Chief in the Absence of the Chief.

CONTENTS.

INTRODUCTION.

Roaches are among the commonest and most offensive of the insects which frequent human habitations. They were well known to the ancients, who called them *lucifuga*, from their habit of always shunning the light. The common English name for them, or, more properly, for the common domestic English species, is "black beetle." In America this name has not been adopted to any extent for this insect, which was early introduced here, and the term "roach," or "cockroach," is the common appellation of all the domestic species. The little German roach, however, is very generally known as the "Croton bug," or "water bug," from its early association with the Croton waterworks system in New York City. The popular designations of this insect in Germany illustrate in an amusing way both sectional and racial prejudices. In north Germany these roaches are known as "Schwaben," a term which applies to the inhabitants of south Germany, and the latter section retaliates by calling them "Preussen," after the north Germans. In east Germany they are called "Russen," and in west Germany "Franzosen," the last two appellations

NOTE.—This bulletin is of special interest to housekeepers throughout the United States. It is a revision of Circular No. 51 of the Bureau of Entomology, U. S. Department of Agriculture.

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indicating a certain national antipathy to rival countries as well as a fanciful idea as to origin. Still other names are "Spanier," dating from the time of Charles V, and "Däne," from Denmark.

DISTRIBUTION AND HISTORY.

The roaches belong to a very extensive family, the Blattidæ, comparatively few of which, fortunately, have become domesticated. In temperate countries some four or five species are very common household pests, and a few occur wild in the woods; but they are essentially inhabitants of warm countries, and in the Tropics the house species are very numerous, and the wild species occur in great number and

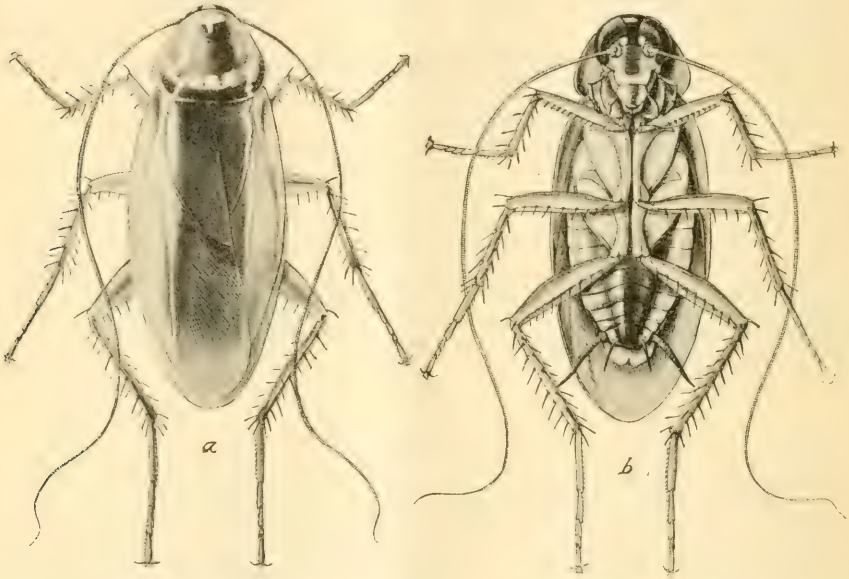

FIG. 1.—The American roach (*Periplaneta americana*): *a*, View from above; *b*, from beneath. Both enlarged one-third. (Author's illustration.)

variety, many of them being striking in shape, coloration, and size, one species expanding more than 6 inches. The inability of the domestic roaches to withstand unusual cold was illustrated by the fact that the severe weather in the winter of 1894 in Florida, which was so destructive to the citrus groves, on the authority of Mr. H. G. Hubbard destroyed all the roaches, even those in houses, except a few unusually well protected. Under suitable conditions in the more northern latitudes the domestic species often multiply prodigiously, and even in the far north a species occurs in the huts of the Laplanders, and sometimes entirely devours the stores of dried fish put away for winter consumption.

While the domestic species are few in number, nearly a thousand species of Blattidæ have been described and preserved in collections, and it is estimated that perhaps upward of 5,000 species occur at the present time in different parts of the world. The great majority of the roaches live outdoors, and in warm countries have the reputation of living on plants and sometimes being very injurious. This belief has been recently questioned by Mr. J. G. O. Tepper, of South Australia, who states that in his experience these insects are eminently carnivorous, feeding on caterpillars and other soft-bodied insects, and that with the increase of certain species in his gardens, notably *Epilampra notabilis*, "the herbivorous larvæ disappear rapidly." Mr. Tepper points out that the injury to plants occasionally noted where roaches are abundant may very possibly be due to other insects or to snails which again have attracted the roaches and on which the latter feed. That roaches will eat fruits and the starchy tubers and other products of plants is a common observation, but that they ever subsist on the green foliage of plants may be open to doubt.

The roach is one of the most primitive and ancient insects, in the sense of its early appearance on the globe, fossil remains of roaches occurring in abundance in the early coal formations, ages before the more common forms of insect life of the present day had begun to appear. The species now existing are few in number in comparison with the abundance of forms in the Carboniferous age, which might with propriety be called the age of cockroaches, the moisture and warmth of that distant period being alike favorable to plant growth and to the multiplication of this family of insects.

The house roaches of to-day were undoubtedly very early associated with man in his primitive dwellings, and through the agency of commerce have been carried to all quarters of the globe. On shipboard they are always especially numerous and troublesome, the moisture and heat of the vessels being particularly favorable to their development. It is supposed that the common oriental cockroach, or so-called "black beetle," of Europe [1] is of Asiatic origin, and it is thought to have been introduced into Europe in the last two or three hundred years. The original home of this and the other common European species [2] is, however, obscure, and in point of fact they have probably both been associated with man from the earliest times, and naturally would come into the newly settled portions of Europe from the older civilizations of Asia and Egypt.

Of the other two domestic species especially considered in this paper, the Australian roach,[3] as its name implies, is a native of Australia, and the American roach,[4] of subtropical and tropical America.

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[1] *Blatta orientalis* L.

[2] *Blattella germanica* L.

[3] *Periplaneta australasiæ* Fab.

[4] *Periplaneta americana* L.

Rarely do two of the domestic species occur in any numbers together in the same house. Often also of two neighboring districts one may be infested with one species, while in the other a distinct species is the commoner one. The different species are thus seemingly somewhat antagonistic, and it is even supposed that they may prey upon one another, the less numerous species being often driven out.

STRUCTURAL CHARACTERISTICS.

Although among the oldest insects geologically, roaches have not departed notably from the early types, and form one of the most persistent groups among insects. The house species are rather uniformly dark brown or dark colored, a coloration which corresponds with their habit of concealment during daylight. They are smooth and slippery insects, and in shape broad and flattened. The head is inflexed under the body, so that the mouth parts are directed backward and the eyes directed downward, conforming with their groveling habits. The antennæ are very long and slender, often having upward of 100 joints. The males usually have two pairs of wings, the outer ones somewhat coriaceous and the inner ones more membranous and folded once longitudinally. In some species, as, for instance, the black beetle, the females are nearly wingless. The legs are long and powerful and armed with numerous strong bristles or spines. The mouth parts are well developed and have strong biting jaws, enabling these insects to eat all sorts of substances.

HABITS.

In houses roaches are particularly abundant in pantries and kitchens, especially in the neighborhood of fireplaces, on account of the heat. For the same reason they are often abundant in the oven rooms of bakeries or wherever the temperature is maintained above the normal. They conceal themselves during the day behind baseboards, furniture, or wherever security and partial protection from the light are afforded. Their very flat, thin bodies enable them to squeeze themselves into small cracks or spaces where their presence would not be suspected and where they are out of the reach of enemies. Unless routed out by the moving of furniture or disturbed in their hiding places, they are rarely seen, and if so discovered, make off with wonderful celerity, with a scurrying, nervous gait, and usually are able to elude all efforts at their capture or destruction. It may often happen that their presence, at least in the abundance in which they occur, is hardly realized by the housekeeper unless they are surprised in their midnight feasts. Coming into a kitchen or pantry suddenly, a sound of the rustling of numerous objects will come to the ear, and if a light be introduced, often the floor or shelves will be seen covered with scurrying roaches hastening to places of concealment. In districts

where the large American roach occurs they sometimes swarm in this way at night in such numbers that upon entering a small room in which they are congregated one will be repeatedly struck and scratched on the face and hands by the insects in their frantic flight to gain concealment.

The black roach is less active and wary than the others, and particularly the German roach, which is especially agile and shy.

The domestic roaches are practically omnivorous, feeding on almost any dead animal matter, cereal products, and food materials of all sorts. They are also said to eat their own cast skins and egg cases, and it is supposed that they will attack other species of roaches, or are, perhaps, occasionally cannibalistic. They will also eat or gnaw woolens, leather (as of shoes or furniture), and frequently are the cause of extensive damage to the cloth and leather bindings of books in libraries and publishing houses. The sizing or paste used on the cloth covers and in the binding of books is very attractive to them. The surface of the covers of cloth-bound books is often much scraped and disfigured, particularly by the German cockroach,[1] and the gold lettering is sometimes eaten off to get at the albumen paste. On shipboard the damage is often very extensive on account of the vast numbers of cockroaches which frequently occur there, and there are reliable accounts of entire supplies of ship biscuits having been eaten or ruined by roaches.

The damage they do is not only in the products actually consumed, but in the soiling and rendering nauseous of everything with which they come in contact. They leave, wherever they occur in any numbers, a fetid, nauseous odor, well known as the "roachy" odor, which is persistent and can not be removed from shelves and dishes without washing with soap and boiling water. Food supplies so tainted are beyond redemption. This odor comes partly from the excrement, but chiefly from a dark-colored fluid exuded from the mouth of the insect, with which it stains its runways, and also in part, doubtless, from the scent glands, which occur on the bodies of both sexes between certain segments of the abdomen, and which secrete an oily liquid possessing a very characteristic and disagreeable odor. It frequently happens that shelves on which dishes are placed become impregnated with this roachy odor, and this is imparted to and retained by dishes to such an extent that everything served in them, particularly liquids, as coffee or tea, will be noticed to have a peculiar, disgusting, foreign taste and odor, the source of which may be a puzzle, and will naturally be supposed to come from the food rather than from the dish.

The roaches are normally scavengers in habit and may at times be of actual service in this direction by eating up and removing any dead animal material.

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[1] *Blattella germanica L.*

One other redeeming trait has been recorded of them, namely, that they will prey upon that other grievous pest of houses which are not subjected to careful supervision, the bedbug. Their habits in this direction have been recorded several times. One writer, in a narrative of a voyage,[1] makes the following statement in this connection:

> Cockroaches, those nuisances to ships, are plentiful at St. Helena, and yet, bad as they are, they are more endurable than bugs. Previous to our arrival here in the *Chanticleer*, we had suffered great inconvenience from the latter but the cockroaches no sooner made their appearance than the bugs entirely disappeared. The fact is that the cockroach preys upon them and leaves no sign or vestige of where they have been; so far it is a most valuable insect.[2]

The cockroach is, however, far too much of a nuisance itself to warrant its being recommended as a means of eradicating even the much more disagreeable insect referred to.[3]

The local spread of roaches from house to house is undoubtedly often effected by their introduction with supplies, furniture, goods, etc. That the Croton bug, or German roach, and probably the other species also, may develop a migratory instinct has been witnessed by Dr. Howard and the writer in Washington.[4] This very interesting instance of what seems to have been a true migration, in which an army of thousands of roaches by one common impulse abandoned their old quarters and started on a search for a more favorable location, illustrates, as pointed out by Dr. Howard, what is probably of frequent occurrence under the cover of darkness, and accounts for the way in which new houses frequently become suddenly overrun with these vermin.

TRANSFORMATION.

The roach in its different stages from egg to adult shows comparatively little variation in appearance or habits. The young are very much like the adults, except in point of size and in lacking wings, if the latter be winged in the adult state. In their mode of oviposition

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[1] Foster, Henry. Narrative of a voyage to the Southern Atlantic Ocean in the years 1828, 29, 30, v. 1, p. 373-374, London, 1834.

[2] Proc. Ent. Soc. Lond., 1855, n. s. v. 3, p. 77.

[3] The following interesting letter from Mr. Herbert H. Smith, the collector and naturalist, gives a vivid picture of the roach nuisance in the Topics:

Cockroaches are so common in Brazilian country houses that nobody pays any attention to them. They have an unpleasant way of getting into provision boxes, and they deface books, shoes, and sometimes clothing. Where wall paper is used they soon eat it off in unsightly patches, no doubt seeking the paste beneath. But at Corumba, on the upper Paraguay, I came across the cockroach in a new rôle. In the house where we were staying there were nearly a dozen children, and everyone of them had their eyelashes more or less eaten off by cockroaches—a large brown species, one of the commonest kind throughout Brazil. The eyelashes were bitten off irregularly, in some cases quite close to the lid. Like most Brazilians, these children had very long, black eyelashes, and their appearance thus defaced was odd enough. The trouble was confined to children, I suppose because they are heavy sleepers and do not disturb the insects at work. My wife and I sometimes brushed cockroaches from our faces at night, but thought nothing more of the matter. The roaches also bite off bits of the toenails. Brazilians very properly encourage the large house spiders, because they tend to rid the house of other insect pests.

[4] U. S. Dept. Agr., Div. Ent., Insect Life, v. 7, no. 4, p. 349, March, 1895.

they present, however, a very anomalous and peculiar habit. The eggs, instead of being deposited separately, as with most other insects, are brought together within the abdomen of the mother into a hard, horny pod or capsule which often nearly fills the body of the parent. This capsule contains a considerable number of eggs, the number varying in the different species, arranged in two rows, the position of the eggs being indicated on the exterior of the capsule by transverse lateral impressions. When fully formed and charged with eggs the capsule is often partly extruded from the female abdomen and retained in this position sometimes for weeks, or until the young larvæ are ready to emerge. The capsule is oval, elongate, or somewhat bean shaped, and one of its edges is usually serrate. The young are in some instances assisted to escape by the parent, who with her feet aids in splitting the capsule on the serrate edge to facilitate their exit. On hatching, it is said the young are often kept together by the parent and brooded over and cared for, and at least a colony of young will usually be found associated with one or two older individuals. These insects are more or less gregarious, notably so in the case of the black beetle of Europe and to a less extent with the German and American roaches.

FIG. 2.—Egg capsule of *Periplaneta americana*: *a*, Side; *b*, end view. Natural size indicated by outline figure. (Author's illustration.)

They pass through a variable number of molts, sometimes as many as seven, the skin splitting along the back and the insects coming out white, soft, but rapidly hardening and assuming the normal color. Some astounding statements have been made as to the length of time required for the development of the roach from the egg to the adult. Four or five years have been said to be necessary for an individual to reach full growth; but more recent breeding experiments have not altogether confirmed these statements. Their development, however, is unquestionably slow, and probably under the most favorable conditions rarely is more than one generation per year produced. In colder countries the breeding and growth are practically restricted to the warm season. During the winter months they go into concealment and partial hibernation. *Blattella germanica* has been shown to reach full growth in a variable period of from four and a half to six months.[1] The common American roach [2] has been carried from the egg to the adult state in the insectary. Young hatching July 11 from an egg case received from Eagle Pass, Tex., reached the adult stage between March 14 and June 12 of the following year, indicating a period of nearly 12 months for complete development. The rate of growth of the roach undoubtedly depends

[1] Hummel, Essais Entomologiques, No. 1, St. Petersburg, 1821. [2] *Periplaneta americana* L.

very largely on food and temperature, and under unfavorable conditions the time required for development may undoubtedly be vastly lengthened. The abundance of roaches is, therefore, apparently not accounted for so much by their rapidity of multiplication as by their unusual ability to preserve themselves from ordinary means of destruction and by the scarcity of natural enemies.

THE COMMON DOMESTIC ROACHES.

The four roaches which have been made the subject of illustrations represent the species which occur most commonly in houses, bakeries, or on shipboard. The numerous tropical house species, many of which are perhaps only partially domesticated, and the subarctic roach of high altitudes and of the extreme north have been omitted.

The American roach [1] (fig. 1) is the native or indigenous species of this continent, originating, it is supposed, in tropical or subtropical America.

An ancient and rather quaint account of the American roach indicates that this species early came to the notice of our forefathers.[2] Its domesticity doubtless resulted from ages of association with the aborigines. It has now become thoroughly cosmopolitan and is unquestionably the most injurious and annoying of the species occurring on vessels. It is sometimes numerous also in greenhouses, causing considerable injury to tender plants. It is a notorious house pest and occasionally vies with the German roach in its injuries to book bindings. One of the most serious cases of injury of this sort was reported by the Treasury Department. The backs of both cloth and leather bound books were sometimes entirely eaten off to get at the starchy paste used in the binding.[3]

This roach is very abundant in the Middle and Western States, where until recently it has been practically the only troublesome house species. In the East it is not often so common as are one or other of the following species, and especially *germanica*. In foreign countries it has not become widespread and is largely confined to seaport towns. In size it is larger than any of the other domestic species, and it is light brown in color, the wings being usually long, powerful, and well developed in both sexes.

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[1] *Periplaneta americana* L.

[2] *The cockroach.*—These are very troublesome and destructive vermin, and are so numerous and voracious that it is impossible to keep victuals of any kind from being devoured by them without close covering. They are flat, and so thin that few chests or boxes can exclude them. They eat not only leather, parchment, and woolen, but linen and paper. They disappear in winter and appear most numerous in the hottest days in summer. It is at night they commit their depredations, and bite people in their beds, especially children's fingers that are greasy. They lay innumerable eggs, creeping into the holes of old walls and rubbish, where they lie torpid all the winter. Some have wings and others are without—perhaps of different sexes.—Catesby, Mark. Natural history of Carolina, Florida, and the Bahama Islands, v. 2, Appendix, p. 10, London, 1748.

[3] U. S. Dept. Agr., Div. Ent., Insect Life, v. 1, no. 3, p. 67–70, September, 1888.

The Australian roach[1] (fig. 3) resembles very closely the last species, but differs strikingly in the brighter and more definitely limited yellow band on the prothorax and in the yellow dash on the sides of the upper wings. In the United States it is the most abundant and troublesome species in Florida and some of the other Southern States. It is already practically cosmopolitan.

The oriental cockroach, or "black beetle,"[2] is the common European and particularly the English species, and is notable for the fact that the female is nearly wingless in the adult state. The wings of the male also are shortened, not reaching to the extremity of the body.

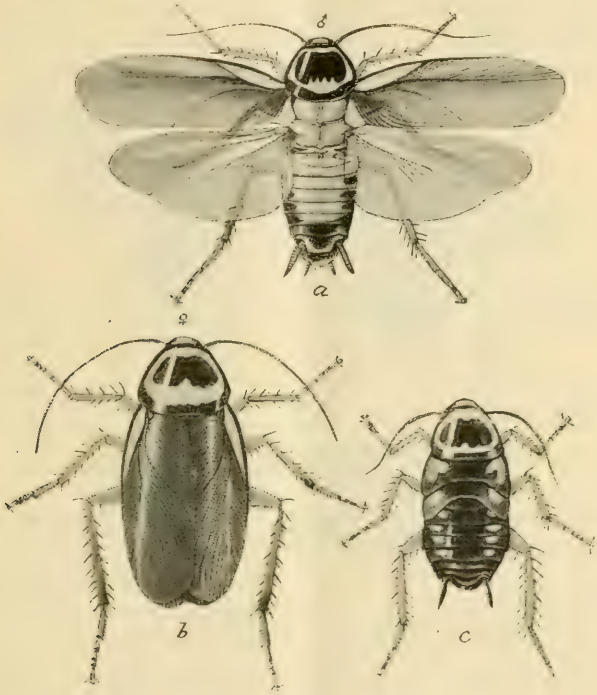

FIG. 3.—The Australian roach (*Periplaneta australasiæ*): *a*, Male with spread wings; *b*, female; *c*, pupa. All life size. (Author's illustration.)

In color it is very dark brown, almost black, shining, and rather robust, much stouter than the other species, making its English name of "black beetle" quite appropriate. This species is notably gregarious in habit, individuals living together in colonies in the most amicable way, the small ones being allowed by the larger ones to sit on them, run over them, and nestle beneath them without any resentment being shown. This species was a common and troublesome pest in the British colonies early in the eighteenth century, although unknown at the same time in the French Canadian possessions.[3]

[1] *Periplaneta australasiæ* Fab.
[2] *Blatta orientalis* L.
[3] Kalm, Peter. Travels into North America, ed. 2, v. 1, p. 321–323; v. 2, p. 256. London, 1772.

It then seemed to be commonly known as the mill beetle. The early Dutch called them *Kakerlach*, and in the Swede settlements they were known as *Brodætare* (bread eaters). It is now very common in houses in the East, but is quite generally distributed, and is the common species even so far removed from the Atlantic seaboard as New Mexico. The characteristics of this insect are shown in the accompanying illustration (fig. 4).

The German cockroach [1] is particularly abundant in Germany and neighboring European countries, but, like most of the other domestic species, has become world-wide in distribution. In this country it is very often styled the Croton bug, this designation coming from the fact, already alluded to, that attention was first permanently

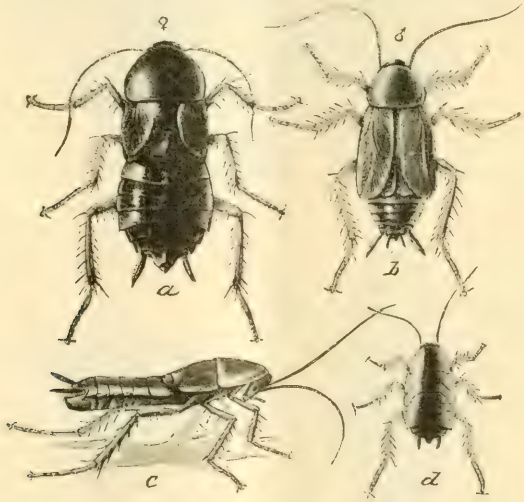

FIG. 4.—The Oriental roach (*Blatta orientalis*): *a*, Female; *b*, male; *c*, side view of female; *d*, half-grown specimen. All natural size. (Author's illustration.)

drawn to it at the time of the completion of the Croton system of waterworks in New York City. It had probably been introduced long previously, but the extension of the waterworks system and of piping afforded it means of ingress into residences and greatly encouraged its spread and facilitated its multiplication. The dampness of water pipes is favorable to it, and it may be carried by the pressure of the water long distances through the pipes without injury. This roach has so multipled in the eastern United States that it has now become the commonest and best known of the domestic species, and its injuries to food products, books, etc., and the disgusting results of its presence in pantries, storehouses, and bakeries give it really a greater economic importance than any of the other species.

[1] *Blattella germanica* L.

It is very light brown in color, and characteristically marked on the thorax with two dark-brown stripes. It is more active and wary than the larger species and much more difficult to eradicate. It is the smallest of the domestic species, rarely exceeding five-eighths of an inch in length, and multiplies much more rapidly than the others, the breeding period being shorter and the number of eggs in the capsules greater than with the larger roaches. The injuries effected by it to cloth-bound reports have been the source of very considerable annoyance at the Department of Agriculture and in the large libraries of

FIG. 5.—The German roach (*Blattella germanica*): *a*, First stage; *b*, second stage; *c*, third stage; *d*, fourth stage; *e*, adult; *f*, adult female with egg case; *g*, egg case, enlarged; *h*, adult with wings spread. All natural size except *g*. (From Riley.)

eastern towns and colleges. The characteristics of the different stages, from the egg to the adult, are shown in the illustration (fig. 5).

NATURAL ENEMIES AND PARASITES.

In Europe the egg capsules of the cockroach are often parasitized by an ichneumon fly.[1] This insect has become widely distributed over the world following its host insect, and has been redescribed under a great many different names. It was found in Cuba as early as 1829, and has been several times collected in the United States. Unfortunately, its usefulness as a means of keeping the roach in check by destroying the egg capsules is greatly impaired by the occurrence of another ichneumon fly,[2] which is parasitic upon the first. This is also a European species which has been brought over with its host parasite. If the true egg-capsule parasite of the roach could have been introduced into this country without this secondary parasite its usefulness would doubtless have been very much greater. The secondary parasite, however, seems to have been introduced early, and has been found in Cuba and Florida, and probably occurs as widely as its host and prevents the latter from multiplying very greatly. Among other natural enemies of the roach are tree frogs; and a correspondent informs us that if these animals are inclosed in a room overnight they will effectively clear it of roaches.

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[1] *Evania appendigaster* L.

[2] *Entedon hagenowi* Ratzb.

REMEDIES.

Like the crows among birds, the roaches among insects are apparently unusually well endowed with the ability to guard themselves against enemies, displaying great intelligence in keeping out of the way of the irate housekeeper and in avoiding food or other substances which have been doctored with poison for their benefit. Their keenness in this direction may be the accumulated inheritance of many centuries during which the hand of man has ever been raised against them. Roaches may be controlled by the use of (1) poisons and repellents; (2) fumigants; and (3) trapping.

POISONS AND REPELLENTS.

As just noted, roaches often seem to display a knowledge of the presence of poisons in food, and, notwithstanding their practically omnivorous habits, a very little arsenic in baits seems to be readily detected by them. In attempting to eradicate roaches from the department storerooms where cloth-bound books are kept various paste mixtures containing arsenic were tried, but the roaches invariably refused to feed on them in the least. This applies particularly to the German roach, or Croton bug, and may not hold so strongly with the less wary and perhaps less intelligent larger roaches.

Sodium fluorid.—One of the most effective simple means of ridding premises of roaches is dusting with commercial sodium fluorid, either pure or diluted one-half with some inert substance such as powdered gypsum or flour. Numerous practical tests conducted in lunch rooms, bakeries, milk-bottle exchanges, etc., in Washington by Messrs. E. W. Scott, W. S. Abbott, and W. H. Sill, working under the direction of Mr. A. L. Quaintance, of the Bureau of Entomology of this department, have shown that with the use of this substance roaches can be completely exterminated with very little trouble and cost and with none of the possible dangers which attend the use of hydrocyanic-acid gas, another efficient control method referred to below under the subject of fumigation. With the use of some dust gun or blower the sodium fluorid can be thoroughly dusted over the shelves, tables, floors, and the runways and hiding places of the roaches. The immediate effect is to cause these insects to come out of their retreats and rush about more or less blindly, showing evidence of discomfort, to be eventually followed in the course of a few hours by their death. These dead or paralyzed roaches can be swept up and burned, and complete extermination is effected within 24 hours. It is not definitely known whether the sodium fluorid acts as a contact insecticide through the breathing pores or as a stomach poison. Probably, however, it acts in both ways, inasmuch as it has been found to kill caterpillars fed on foliage dusted with this substance.

Borax.—Powdered borax enters into the composition of many of the so-called roach powders. This substance may be used either pure as a poison or repellent or mixed with some other substance to render it attractive to the insects. Several correspondents have reported great success from the use of a mixture consisting of 1 part powdered borax to 3 parts of finely pulverized chocolate, this mixture to be freely sprinkled about the infested premises.

Pyrethrum.—Another common remedy consists in the liberal use of pyrethrum powder or buhach. This is at best but a temporary expedient, but if persisted in considerable relief will be gained. To be at all effective it must be fresh and liberally applied. The roaches are often paralyzed by it rather than killed outright, and the morning after the application all paralyzed and dead roaches should be swept up and burned.

Sulphur.—Flowers of sulphur dusted about where roaches abound has also proved, on the authority of Mr. A. I. Mudd, of this department, very effective as a repellent.

Phosphorus.—Of the proprietary substances, perhaps one of the oldest and most efficient is a form of phosphorus paste. It consists of sweetened flour paste containing 1 to 2 per cent of phosphorus, and may be distributed on bits of paper or cardboard placed in the runways of the roaches. It has been used very successfully in the offices of this department to free desks from Croton bugs, numbers of dead insects being found in the drawers every day during the time the poison was kept about. It also has some repellent value.

FUMIGANTS.

Hydrocyanic-acid gas.—Hydrocyanic-acid gas fumigation is a thoroughly effective means of ridding premises of roaches, but involves considerable cost, difficulty of application, and the necessity of taking extreme precautions on account of the deadly nature of the gas to higher animals, including human beings. A special publication, which may be had on application, has been issued by the Department of Agriculture giving the steps of the process in detail.

Carbon bisulphid.—Wherever roaches infest small rooms or apartments which may be sealed up nearly air-tight, and also on shipboard, the roach nuisance can be greatly abated by the proper use of carbon bisulphid. This substance, distributed about a pantry or room in open vessels, will evaporate, and, if used at the rate of 1 pound to every 1,000 cubic feet of room space, will destroy roaches. Unless the room can be very tightly sealed up, however, the vapor dissipates so rapidly that its effect will be lost before the roaches are killed. The hatches of ships, especially of smaller coasting vessels, may be battened down, a very liberal application of carbon bisulphid having been previously made throughout the interior. If left for 24 hours

the roaches and all other vermin will unquestionably have been destroyed. *In the use of this substance it must be always borne in mind that it is violently explosive in the presence of fire, and every possible precaution should be taken to see that no fire is in or about the premises during the treatment.* It is also deadly to higher animals, and compartments should be thoroughly aired after fumigation.

Pyrethrum fumes.—A safer remedy of the same nature consists in burning pyrethrum in the infested apartment. The smoke and vapors generated by the burning of this insecticide are often more effective in destroying roaches than the application of the substance in the ordinary way as a powder. There is no attendant danger of explosion, and the only precaution necessary is to see that the room is kept tightly closed for from 6 to 12 hours.

TRAPPING.

Various forms of traps have been very successfully employed in England and on the Continent of Europe as a means of collecting and destroying roaches. These devices are all so constructed that the roaches may easily get into them and can not afterwards escape. The destruction of the roaches is effected either by the liquid into which they fall or by dousing them with hot water. A few of the common forms of traps and the methods of using them are here described.

A French trap consists of a box containing an attractive bait, the cover of which is replaced by four glass plates inclined toward the center. The roaches fall from the covering glasses into the box and are unable to escape. A similar trap used in England is described by Westwood. It consists of a small wooden box in which a circular hole is cut in the top and fitted with a glass ring, so that it is impossible for the roaches to escape. This trap is baited nightly, and the catch thrown each morning into boiling water.

A simpler form of trap, which the late F. C. Pratt reported as being very successfully used in London, England, consists of any deep vessel or jar, against which a number of sticks are placed, and bent over so that they project into the interior of the vessel for a few inches. The vessel is partially filled with stale beer or ale, a liquid for which roaches seem to have a special fondness. In the morning these vessels are found charged with great quantities of dead and dying roaches, which have climbed up the inclined sticks and slipped off into the vessel. This last method has given fairly successful results against the Oriental roach in Washington, but against the more wary and active Croton bug it is comparatively worthless.

A simple and practical method of trapping roaches in large numbers was devised by a correspondent in Brockton, Mass. He took several tin bread pans with nearly vertical sides about 3 inches in height,

greased the bottoms and sides with a little rancid butter, and placed them where the roaches were numerous. Each pan in the morning contained hundreds of the pests unable to climb out because of the greased sides. The roaches were shaken out into hot water, and the pans were again ready for use, without regreasing.

Traps of the sort described above, placed in pantries and bakeries, will unquestionably destroy great quantities of roaches, and keep them in check and thus obviate the use of insect powders or the distribution of poisoned baits.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 659 APRIL 5, 1915.

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE TRUE CLOTHES MOTHS.[1]

By C. L. MARLATT,

Entomologist and Acting Chief in Absence of Chief.

CONTENTS.

INTRODUCTION.

The destructive work of the larvæ of the small moths commonly known as clothes moths, and also as carpet moths, fur moths, etc., in woolen fabrics, fur, and similar material during the warm months of summer in the North, and at any season in the South, is an altogether too common experience. The preference they so often show for woolen or fur garments gives these insects a much more general interest than is perhaps true of any other household pest.

The little yellowish or buff-colored moths sometimes seen flitting about rooms, attracted to lamps at night, or dislodged from infested garments or portieres, are themselves harmless enough, and in fact their mouth parts are rudimentary, and no food whatever is taken in the winged state. The destruction occasioned by these pests is,

[1] A reprint, with slight revision, of Circular No. 36, Bureau of Entomology, U. S. Dept. of Agriculture.

NOTE.—This bulletin is of interest to housekeepers and those who have anything to do with fur and wool, in either the raw or the manufactured state.

therefore, limited entirely to the feeding or larval stage. The killing of the moths by the aggrieved housekeeper, while usually based on the wrong inference that they are actually engaged in eating her woolens, is, nevertheless, a most valuable proceeding, because it checks in so much the multiplication of the species, which is the sole duty of the adult insect.

The clothes moths all belong to the group of minute Lepidoptera known as Tineina, the old Latin name for cloth worms of all sorts, and are characterized by very narrow wings fringed with long hairs. The common species of clothes moths have been associated with man from the earliest times and are thoroughly cosmopolitan. They are all probably of Old World origin, none of them being indigenous to the United States. That they were well known to the ancients is shown by Job's reference to "a garment that is moth eaten," and Pliny has given such an accurate description of one of them as to lead to the easy identification of the species. That they were early introduced into the United States is shown by Pehr Kalm, a Swedish scientist, who took a keen interest in house pests. He reported these tineids to be abundant in 1748 in Philadelphia, then a straggling village, and says that clothes, worsted gloves, and other woolen stuffs hung up all summer were often eaten through and through by the worms, and furs were so ruined that the hair would come off in handfuls.

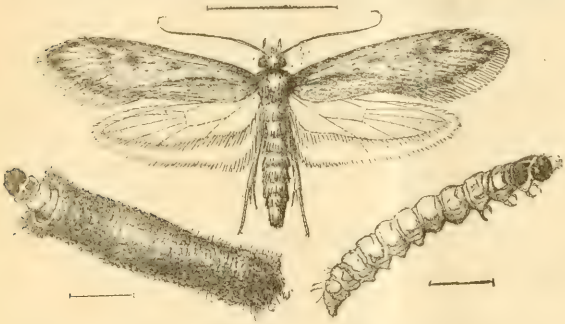

FIG. 1.—*Tinea pellionella:* Above, adult; at right, larva; at left, larva in case. Enlarged. (From Riley.)

What first led to the association of these and other household pests with man is an interesting problem. In the case of the clothes moths, the larvæ of all of which can, in case of necessity, still subsist on almost any dry animal matter, their early association with man was probably in the rôle of scavengers, and in prehistoric times they probably fed on waste animal material about human habitations and on fur garments. The fondness they exhibit nowadays for tailor-made suits and other expensive products of the loom is simply an illustration of their ability to keep pace with man in his development in the matter of clothing from the skin garments of savagery to the artistic products of the modern tailor and dressmaker.

Three common destructive species of clothes moths occur in this country. Much confusion, however, exists in all the early writings on these insects, all three species being inextricably mixed in the

descriptions and accounts of habits. Collections of these moths were submitted some years ago by Profs. Fernald and Riley to Lord Walsingham, of Merton Hall, England, the world's authority on tineids, and from the latter's careful diagnosis it is now possible to separate and recognize the different species easily.

The common injurious clothes moths are the case-making species,[1] the webbing species or southern clothes moth,[2] and the gallery species or tapestry moth.[3]

A few other species, which normally infest animal products, may occasionally also injure woolens, but are not of sufficient importance to be noted here.

THE CASE-MAKING CLOTHES MOTH.

The case-making clothes moth [1] (fig. 1) is the only species which constructs for its protection a true transportable case. It was characterized by Linnæus, and carefully studied by Réaumur, early in the last century. Its more interesting habits have caused it to be often a subject of investigation, and its life history will serve to illustrate the habits of all the clothes moths.

The moth expands about half an inch, or from 10 to 14 millimeters. Its head and forewings are grayish yellow, with indistinct fuscous spots on the middle of the wings. The hind wings are white or grayish and silky. It is the common species in the North, being widely distributed and very destructive. Its larva feeds on woolens, carpets, etc., and is especially destructive to furs and feathers. In the North it has but one generation annually, the moths appearing from June to August, and, on the authority of Prof. Fernald, even in rooms kept uniformly heated night and day it never occurs in the larval state in winter. In the South, however, it appears from January to October, and has two or even more broods annually.

The larva is a dull white caterpillar, with the head and the upper part of the next segment light brown, and is never seen free from its movable case or jacket, the construction of which is its first task. If it be necessary for it to change its position, the head and first segment are thrust out of the case, leaving the thoracic legs free, with which it crawls, dragging its case after it, to any suitable situation. With the growth of the larva it becomes necessary from time to time to enlarge the case both in length and circumference, and this is accomplished in a very interesting way. Without leaving its case the larva makes a slit halfway down one side and inserts a triangular gore of new material. A similar insertion is made on the opposite side, and the larva reverses itself without leaving the case and makes corresponding slits and additions in the other half. The case is lengthened by successive

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[1] *Tinea pellionella* L. [2] *Tineola biselliella* Hummel. [3] *Trichophaga tapetzella* L.

additions to either end. Exteriorly the case appears to be a matted mass of small particles of wool; interiorly it is lined with soft whitish silk. By transferring the larva from time to time to fabrics of different colors the case may be made to assume as varied a pattern as the experimenter desires, and will illustrate, in its coloring, the peculiar method of making the enlargements and additions described.

On reaching full growth the larva attaches its case by silken threads to the garment or other material upon which it has been feeding, or sometimes carries it long distances. In one instance numbers of them were noticed to have scaled a 15-foot wall to attach their cases in an angle of the cornice of the ceiling. It undergoes its transformations to the chrysalis within the larval case, and under normal conditions the moth emerges three weeks later, the chrysalis having previously worked partly out of the larval case to facilitate the escape of the moth. The latter has an irregular flight and can also run rapidly. It has a distinct aversion to light, and usually conceals itself promptly in garments or crevices whenever it is frightened from its resting place. The moths are comparatively short-lived, not long surviving the deposition of their eggs for a new generation of destructive larvæ. The eggs are minute, not easily visible to the naked eye, and are commonly placed directly on the material which is to furnish the larvæ with food. In some cases they may be deposited in the crevices of trunks or boxes, the newly hatched larvæ entering through these crevices.

In working in feathers this insect occasionally causes a felting very similar to that produced by the black carpet beetle, *Attagenus piceus* Oliv.

The protection afforded by the seclusion of this insect in houses does not prevent its having insect enemies, and at least two hymenopterous parasites have been reared in this country from its larval cases. These are *Exochus ovatus* Davis and *Apanteles carpatus* Say, both reared from specimens collected in Michigan.

THE WEBBING, OR SOUTHERN CLOTHES MOTH.

The webbing, or Southern clothes moth [1] (fig. 2) is the more abundant and injurious species in the latitude of Washington and southward. It occurs also farther north, though in somewhat less numbers than the preceding species. It presents two broods annually even in the Northern States, the first appearing in June from eggs deposited in May, and the second in August and September. It is about the size of *pellionella*. The forewings are, however, uniformly pale ocherous, without markings or spots. Its larva feeds on a large variety of animal substances—woolens, hair, feathers, furs, and in England it has even been observed to feed on cobwebs in the corners of rooms,

[1] *Tineola biselliella* Hummel.

and in confinement has been successfully reared on this rather dainty food substance. The report that it feeds on dried plants in herbaria is rather open to question, as its other recorded food materials are all of animal origin.

Frequently this species is a very troublesome pest in museums, particularly in collections of the larger moths. Prof. F. M. Webster, of the Bureau of Entomology, once had some of his large moths badly riddled by its larvæ, and Hagen also records it as feeding on insect collections. Riley reared it in conjunction with the Angoumois grain moth[1] from grain, it being apparent that its larvæ had subsisted on dead specimens of the grain moth. It is very likely to attack large Lepidoptera on the spreading board, and has, in fact, been carried through several generations on dried specimens of moths.

Its general animal-feeding habit is further indicated by the interesting case reported by Dr. J. C. Merrill, U. S. A., who submitted a sample can of beef meal which had been rejected as "weevilly." The damage proved to be due to the larvæ of *Tineola biselliella*, and goes to substantiate the theory already advanced that clothes moths were scavengers in their earliest association with man.

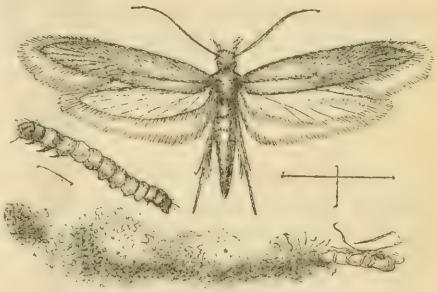

FIG. 2.—*Tineola biselliella:* Moth, larva, cocoon, and empty pupa skin. Enlarged. (From Riley.)

The larva of this moth constructs no case, but spins a silky, or more properly cobwebby, path wherever it goes. When full grown it builds a cocoon of silk, intermixed with bits of wool, resembling somewhat the case of *pellionella*, but more irregular in outline. Within this it undergoes its transformation to the chrysalis, and the moth in emerging leaves its pupal shell projecting out of the cocoon as with the preceding species.

THE TAPESTRY MOTH.

The tapestry moth[2] (fig. 3) is rare in the United States. It is much larger than either of the other two species, measuring three-fourths inch in expansion of wings, and is more striking in coloration. The head is white, the basal third of the forewings black, with the exterior two-thirds of a creamy white, more or less obscured on the middle with gray; the hind wings are pale gray.

This moth normally affects rather coarser and heavier cloths than the smaller species and is more apt to occur in carpets, horse blankets, and

[1] *Sitotroga cerealella* Oliv.

[2] *Trichophaga tapetzella* L.

tapestries than in the finer and thinner woolen fabrics. It also affects felting, furs, and skins, and is a common source of damage to the woolen upholstering of carriages, being rather more likely to occur in carriage houses and barns than in dwelling houses. Its larva enters directly into the material which it infests, constructing burrows or galleries, which it lines more or less completely with silk. Within these galleries it is protected and concealed during its larval life, and later undergoes its transformations without other protection than that afforded by the gallery. The damage is due as much or more to its burrowing than to the actual amount of the material consumed for food.

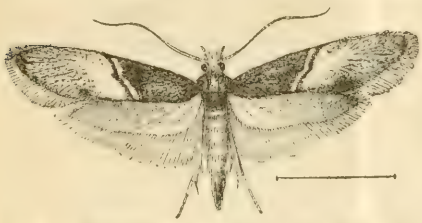

FIG. 3.—*Trichophaga tapetzella:* Adult moth. Enlarged. (From Riley.)

One of the parasites, *Apanteles carpatus* Say, reared from *Tinea pellionella*, has also been reared from the tapestry moth at St. Louis, Mo.

REMEDIES.

There is no easy method of preventing the damage done by clothes moths, and to maintain the integrity of woolens or other materials which they are likely to attack demands constant vigilance, with frequent inspection and treatment. In general, they are likely to affect injuriously only articles which are put away and left undisturbed for some little time. Articles in daily or weekly use, and apartments frequently aired and swept, or used as living rooms, are not apt to be seriously affected. Carpets under these conditions are rarely attacked, except sometimes around the borders, where the insects are not so much disturbed by walking and sweeping. Agitation, such as beating, shaking, or brushing, and exposure to air and sunlight, are old remedies and still among the best at command. Various repellents, such as tobacco, camphor, naphthaline cones or balls, and cedar chips or sprigs, have a certain value if the garments are not already stocked with eggs or larvæ. The odors of these repellents are so disagreeable to the parent moths that they are not likely to come to deposit their eggs as long as the odor is strong. As the odor weakens the protection decreases, and if the eggs or larvæ are already present, these odors have no effect on their development; while if the moths are inclosed with the stored material to be protected by these repellents, so that they can not escape, they will of necessity deposit their eggs, and the destructive work of the larvæ will be little, if at all, restricted. After woolens have been given a vigorous and thorough treatment and aired and exposed to sunlight, however, it is of some advantage in packing them away to inclose with them any of the repellents mentioned. Cedar chests and wardrobes are of value in proportion to the

freedom of the material from infestation when stored away; but, as the odor of the wood is largely lost with age, in the course of a few years the protection greatly decreases. Furs and such garments may also be stored in boxes or trunks which have been lined with heavy tar paper used in buildings. New papering should be given to such receptacles every year or two. Similarly, the tarred paper moth bags obtainable at dry-goods houses are of some value; always, however, the materials should first be subjected to the treatment outlined above.

To protect carpets, clothes, and cloth-covered furniture, furs, etc., these should be thoroughly beaten, shaken, brushed, and exposed as long as practicable to the sunlight in early spring, either in April, May, or June, depending on the latitude. The brushing of garments is a very important consideration, to remove the eggs or young larvæ which might escape notice. Such material can then be hung away in clothes closets which have been thoroughly cleaned, and, if necessary, sprayed with benzine about the cracks of the floor and the baseboards. If no other protection be given, the garments should be examined at least once a month during summer, brushed, and, if necessary, exposed to the sunlight.

It would be more convenient, however, so to inclose or wrap up such material as to prevent the access of the moths to it, after it has once been thoroughly treated and aired. This can be easily effected in the case of clothing and furs by wrapping tightly in stout paper or inclosing in well-made bags of cotton or linen cloth or strong paper. Dr. L. O. Howard has adopted a plan which is inexpensive, and which he has found eminently satisfactory. For a small sum he secures a number of the large pasteboard boxes, such as tailors use, and in these packs away all winter clothing, gumming a strip of wrapping paper around the edge, so as to seal up the box completely and leave no cracks. These boxes with care will last many years. With thorough preliminary treatment it will not be necessary to use the tar-impregnated paper sacks sold as moth protectors, which may be objectionable on account of the odor.

In the case of furniture or carriages, covered or lined with woolen cloth, stored or left unused for the summer, examination and thorough brushing should be given at least monthly. Spraying monthly with benzine or naphtha or sponging with dilute corrosive sublimate has been recommended, but due regard should be given to the inflammability of these sprays and to the poisonous nature of the corrosive sublimate.

The method of protection adopted by one of the leading furriers of Washington, D. C., who also has a large business and experience in storing costly furs, etc., is practically the course already outlined. Furs when received are first most thoroughly and vigorously beaten with small sticks, to dislodge all loosened hair and the larvæ or moths.

They are then gone over carefully with a steel comb and packed away in large boxes lined with heavy tar roofing paper, or in closets similarly lined with this paper. An examination is made every two to four weeks, and, if necessary at any time, any garment requiring it is rebeaten and combed. During many years of experience in this climate, which is especially favorable to moth damage, this merchant has prevented any serious injury from moths.

COLD STORAGE.

The best method of protection, and the one now commonly adopted by dealers in carpets, furs, etc., is cold storage. In all large towns anyone can avail himself of this means by patronizing storage companies, and safety will be guaranteed.

The most economical degree of cold to be used as a protection from clothes moths and allied insects destructive to woolens and furs has been definitely determined by the careful experiments carried out at the instance of Doctor Howard by Dr. Albert M. Read, manager of a large storage warehouse company in Washington, D. C. These experiments demonstrated that a temperature maintained at 40° F. renders the larval or other stages of these insects dormant and is thoroughly effective. The larvæ, however, are able to stand a steady temperature as low as 18° F. without apparently experiencing any ill results. Doctor Read's experiments have extended over two years, and his later results as reported by Doctor Howard are very interesting. They have demonstrated that while a temperature kept uniformly at 18° F. will not destroy the larvæ of *Tineola biselliella* or of the black carpet beetle,[1] "an alternation of a low temperature with a comparatively high one invariably results in the death of the larvæ of these two insects. For example, if larvæ of either which have been kept at a temperature of 18° F. are removed to a temperature of 40° to 50° F., they will become slightly active and, when returned to the lower temperature and kept there for a little time, will not revive upon a retransfer to the warmer temperature."

It is recommended, therefore, that storage companies submit goods to two or three changes of temperature as noted before placing them permanently in an apartment kept at a temperature of from 40° to 42° F. The maintenance of a temperature lower than the last indicated is needless and a wasteful expense. Where the cost of cold storage is not an item to be seriously considered, the adoption of this method for protection of goods during the hot months is strongly recommended.

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[1] *Attagenus piceus* Oliv.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 662 MAY 11, 1915

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE APPLE-TREE TENT CATERPILLAR.[1]

By A. L. QUAINTANCE,

In Charge of Deciduous Fruit Insect Investigations.

INTRODUCTION.

The conspicuous, unsightly nests or tents of the apple-tree tent caterpillar (fig. 1) are familiar objects in the spring in trees along roadways, streams, and fences, in neglected orchards, and elsewhere.

The gregarious caterpillars construct the tents for their protection, and these, at first small, are gradually enlarged as the larvæ grow, often to a foot or more in height and diameter, the size varying with the number of individuals in the colony. The caterpillars feed upon the foliage of the trees, stripping the leaves from the limbs adjacent to the nest, and if there be several colonies in a tree, as is frequently the case during periods of abundance, the foliage may be quite destroyed, leaving the branches as bare as in midwinter (fig. 2).

DISTRIBUTION AND FOOD PLANTS.

The tent caterpillar is a native American species occurring quite generally in the United States from Canada south to Florida and westward about to the Rocky Mountains. From the Rockies to the Sierras, according to Dyar, the species is replaced by another of the same genus,[2] which ranges from Canada to Mexico, and this latter form in the Pacific Northwest is replaced by still another species.[3]

The tent caterpillar has been a troublesome pest from the earliest times. As stated by Fitch, its injuries in Massachusetts in the years 1646 and 1649 led the early settlers to term these "caterpillar years." At rather long and irregular intervals the caterpillars have been excessively abundant in different parts of their range, but more

[1] *Malacosoma americana* Fab. [2] *Malacosoma fragilis* Stretch. [3] *Malacosoma pluvialis* Dyar.

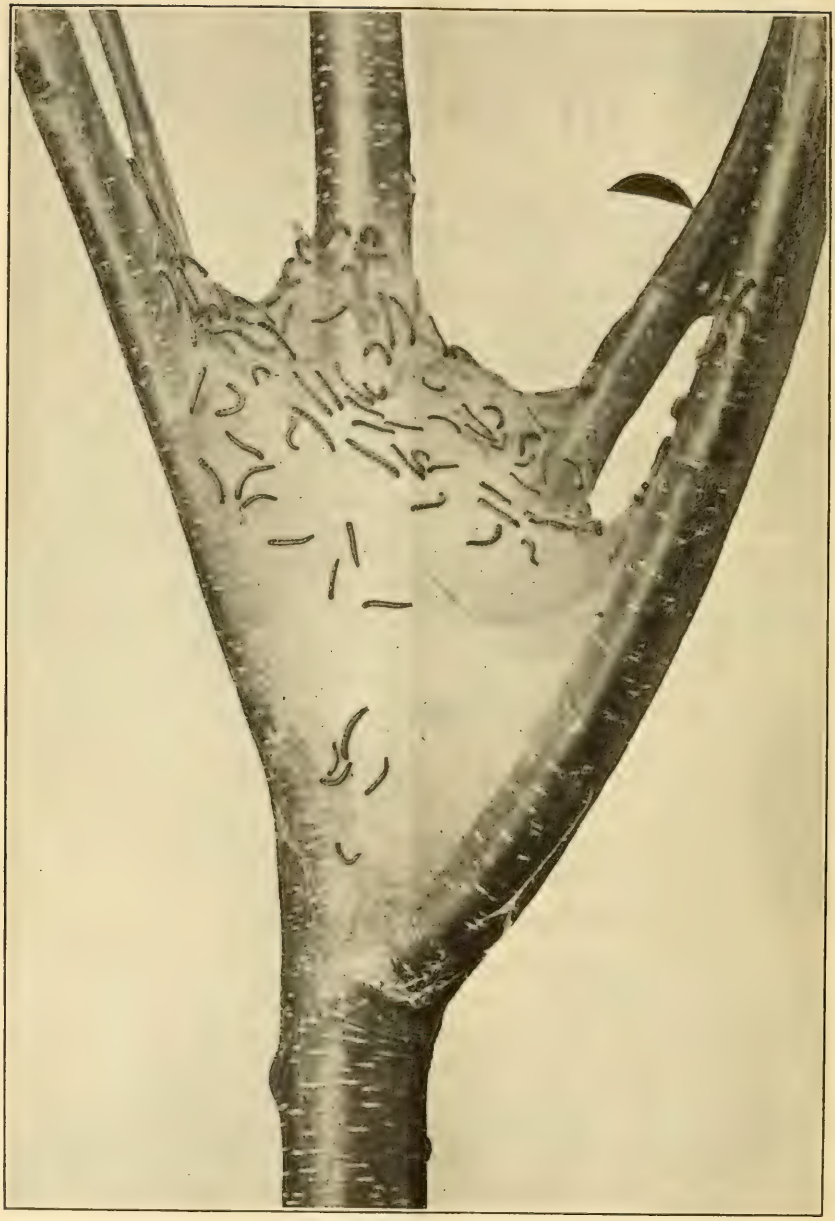

FIG. 1.—Nest and larvæ of apple-tree tent caterpillar in crotch of wild cherry tree. (Original.)

particularly in the New England States. This species was among the first to receive attention by the early American entomologists, and the principal features in its life and habits have been known for many years. Throughout its extended distribution the insect is likely to be abundant each year in one or more localities and often over a considerable territory. Scattered nests are to be found usually during any spring, although in some seasons these are but little in evidence.

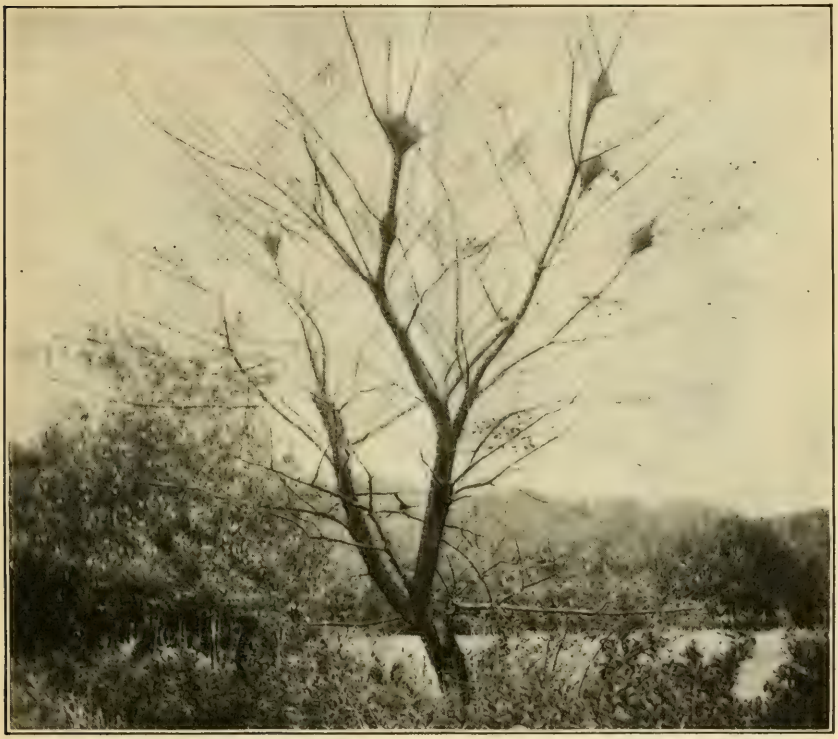

FIG. 2.—Nests of apple-tree tent caterpillar in wild cherry tree which the larvæ have defoliated. (Original.)

The favorite food of the tent caterpillar is the wild cherry, and this is probably its native food plant. Next to the wild cherry the apple is apparently preferred. In the absence of its favorite food, or under special conditions, it attacks many other plants, as plum, peach, thorn, pear, rose, and other members of this group, as also beech, witch-hazel, elm, maple, and various species of willows, oaks, and poplars. During periods of unusual abundance trees are more or less completely defoliated, and at a time when they most need the leaves for their growth or for the development of the fruit, and they are materially weakened, though rarely killed.

DESCRIPTION AND LIFE HISTORY.

THE EGG.

Eggs are deposited in masses or belts encircling the smaller twigs, as shown in figure 3. Different egg masses may vary from one-half to three-fourths of an inch in length and contain from 150 to 250 eggs. The average number of eggs in several egg masses counted by Prof. V. H. Lowe on peach and apple was about 223 each. Each egg belt is deposited by an individual female and ordinarily represents the entire number which she will deposit. Eggs are placed on end, cemented closely together, the whole oval-shaped mass being finally covered with a layer of light-brown frothy glue, which soon becomes tough, brittle, and glistening.

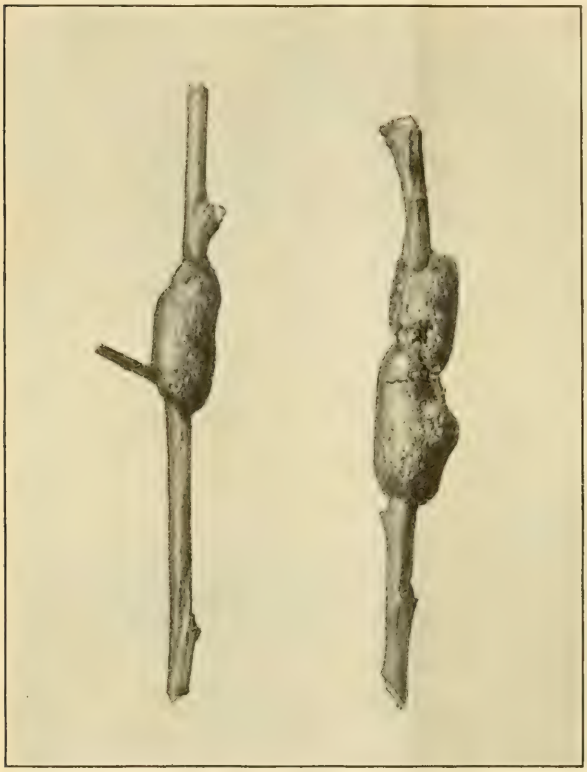

FIG. 3.—Egg masses of apple-tree tent caterpillar. Slightly enlarged. (Original.)

Eggs are deposited by the moths by early midsummer, or earlier in the South, the embryonic larvæ developing so that by fall they are practically full grown, although remaining within the egg until the following spring. With the coming of a warm spell the larvæ escape by gnawing through their eggshells, often before there is foliage out for food, and under these circumstances they may feed upon the glutinous covering of the egg mass.

THE LARVA.

In the presence of food the larvæ begin the formation of their nest in about two days from hatching, usually selecting the crotch formed by two limbs and ordinarily one that is not far from the egg mass. The caterpillars are sociable, those from one egg mass inhabiting one nest and feeding together upon the adjacent leaves. If two egg masses happen to be deposited close together, as on the same or

adjacent twigs, the resulting caterpillars may unite in one nest. Wherever they go each larva spins a thread of silk, the young individuals hanging suspended from a silken thread when they drop, as do the cankerworms and many other larvæ. The nests, at first small and affording but little shelter, are gradually enlarged as the caterpillars grow and soon furnish ample protection. Upon close examination the nests of this species will be found to be made up of layers of silk, with room for the larvæ between the layers. According to Fitch these layers are the result of the caterpillars' habit of lying on the outside of the nest during bright weather, the few restless individuals crawling back and forth over the resting mass, spinning silk

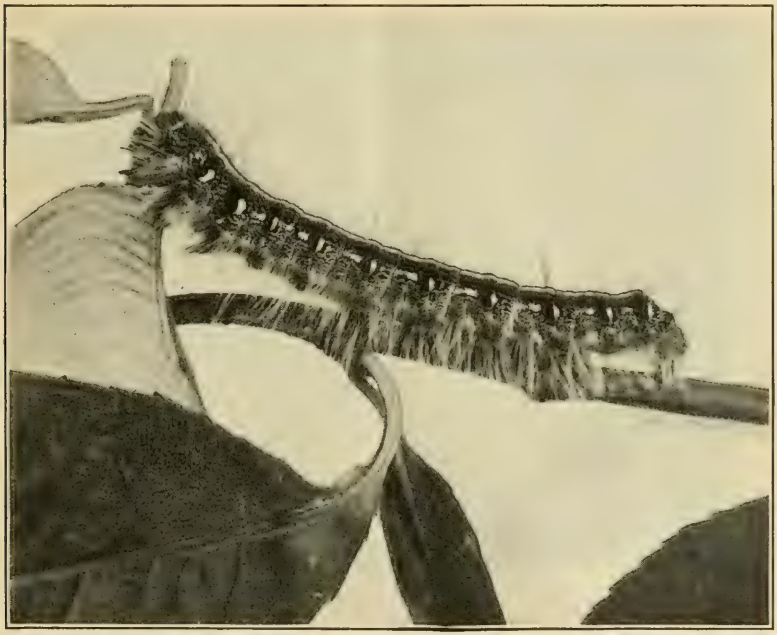

FIG. 4.—Full grown apple-tree tent caterpillar. About twice natural size. (Original.)

as they go, soon forming a new layer. During rainy and cloudy weather the larvæ remain mostly within the nest, but when the weather is favorable they feed at regular intervals; according to Fitch, in the morning, in the afternoon, and again during the night. Upon becoming nearly full grown the larvæ wander singly away from the nest, feeding upon such plants as come to hand. This wandering habit preparatory to pupation results in the scattering of the pupæ and greatly increases the chances of their escape from destruction from their numerous natural enemies.

When full grown the caterpillars are about 2 inches long, cylindrical, deep black, with a white stripe along the back, and lateral markings, as shown in figure 4. On each side is a row of oval pale-

blue spots, one on the middle of each segment, and on the anterior side of each is a broader, deep velvety black spot. The body is sparsely clothed with fine, soft, yellowish hairs of varying length, thickest perhaps toward the anterior end, where they project forward over the black-colored head. In about six weeks from hatching the larvæ become full grown and wander away from the nest, as stated, in search of suitable places for pupation.

THE COCOON.

The larvæ select for pupation any convenient, more or less secluded place, as under loose bark, in grass or brush under trees, along fences, etc. If close to outbuildings the larvæ often make their cocoons in

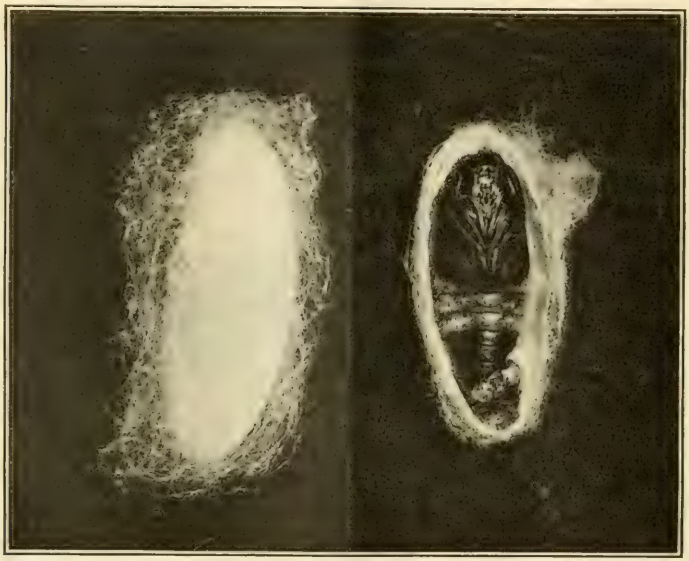

FIG. 5.—Cocoon and pupa of apple-tree tent caterpillar. About twice natural size. (Original.)

the angles along the sides, in window casings, etc. The cocoon, shown in figure 5, at the left, is oval in shape, about 1 inch long, and composed exteriorly of coarse, loose, whitish threads of silk surrounding the tougher parchmentlike lining. The silk of the cocoon is intermixed with a yellow powdery substance, which readily comes off when disturbed. Cocoons are made more or less singly, although in suitable shelter near the nest several may be found spun together, the larvæ taking advantage of the same protection. Cocoons are frequently found within the nest, although these will usually prove to be parasitized.

THE PUPA.

Within the cocoon the larva changes to a short, oval, brownish pupa, as shown in figure 5, at the right. This stage lasts about three weeks, the time varying somewhat; then the moth appears.

THE ADULT.

Both sexes of the tent-caterpillar moth are shown in figure 6, the female to the right. These are dull reddish-brown, stout-bodied moths, with a wing expanse in the females of about 1.5 to 2 inches, and in the males of from 1.2 to 1.3 inches. Obliquely across the forewings of each sex are two nearly parallel whitish lines, as shown in the illustration. Soon after emergence the sexes mate, and eggs are deposited on limbs and twigs. There is only one generation each year, the insects existing in the egg stage throughout the remaining summer and fall and through the winter, the young larvæ coming from the eggs in early spring and forming their nests, or tents, as stated.

FIG. 6.—Moths of apple-tree tent caterpillar; male at the left. Slightly enlarged. (Original.)

NATURAL ENEMIES.

This species is subject to attack by numerous parasitic and predaceous enemies, which undoubtedly exert an important influence in keeping it reduced. Very minute, four-winged flies of the order Hymenoptera deposit their eggs within those of the tent caterpillar moth, the resulting larvæ or grubs finding sufficient food for their growth and development to parent flies. Three egg parasites have been recorded for this species.[1]

Larvæ and pupæ furnish food for a large number of parasites and hyperparasites. Thus W. F. Fiske [2] records a total of some 24 species of insects which directly or indirectly feed upon the tent caterpillar. Eighteen primary parasites have been recorded from the larva and pupa.[3]

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[1] *Telenomus clisiocampae* Riley, *Pteromalus* sp., and *Platygaster* sp.

[2] Tech. Bul. No. 6, N. H. College Agric. Exp. Sta., p. 2 (1903).

[3] *Itoplectis conquisitor* (Say), *Itoplectis annulipes* (Brullé), *Pimplidea pedalis* (Cress.), *Iseropus inquisitoriella* (Dalla Torre), *Limnerium fugitivum* Say, *Ameloctonus clisiocampae* Weed, *Anomalon exile* Prov., *Anomalon anale* Say, *Spilocrytus extrematis* Cress., *Apanteles congregatus* var. *rufocoxalis* Riley, *Apanteles clisiocampae* Ashm., *Rhogas intermedius* Cress., *Hadrobracon hopkinsi* Vier. (mentioned in the reference given above as *Bracon gelechiæ* Ashm., an erroneous determination), *Diglochis omnivorus* Walk., *Miotropis clisiocampae* Ashm., *Theronia melanocephala* Brullé (?)—all Hymenoptera—and the dipteron *Frontina frenchii* Will.

Among predaceous insects are several species of ground beetles which are said to feed upon the larvæ, among them *Calosoma scrutator* Fab. Among the Hemiptera Mr. A. H. Kirkland has observed several species of Podisus[1] and the reduviid, *Diplodus luridus* Stål, attacking the larvæ. According to Prof. Bruner, *Podisus spinosus* Dall. and *Perillus claudus* Say also are enemies of the caterpillar.

While most birds as a rule do not feed on hairy larvæ such as the tent caterpillar, yet several species are known to include this insect in their diet, as the black-billed and yellow-billed cuckoos, the blue-jay, and, according to Mr. E. H. Forbush, the crow, chickadee, Baltimore oriole, red-eyed vireo, chipping sparrow, and yellow warbler. Kirkland states that the common toad feeds greedily on tent caterpillars, he having found in their stomachs the remains of from 15 to 20, and in one instance 37 of these larvæ.

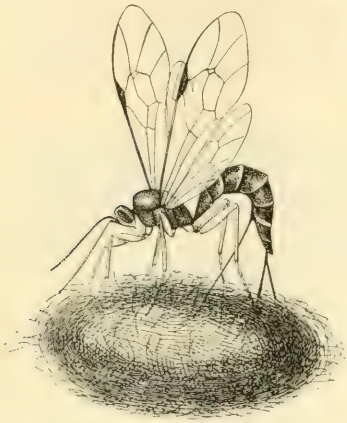

FIG. 7.—Itoplectis in the act of ovipositing on cocoon of apple-tree tent caterpillar. Enlarged. (After Fiske.)

The caterpillars are also subject to destruction by a bacterial disease, especially when they become grown or nearly so, and sick, sluggish individuals may often be observed lying outside at full length on the nest. Larvæ killed by this disease are soft-bodied, the skin easily rupturing and permitting the escape of the liquid, decomposed body contents.

METHODS OF CONTROL.

REMOVAL OF USELESS TREES.

As has been stated, the unsightly nests of the tent caterpillars are especially apt to be found on wild cherry, apple, and other trees growing along roadsides, fences, and elsewhere. In most cases such trees could doubtless be removed without disadvantage, and their removal would greatly reduce the numbers of this pest by lessening their favorite food supply.

COLLECTING THE EGGS.

During the dormant period of trees, when the leaves are off, the egg masses are fairly conspicuous, and with a little practice may be readily found; it is then that the twigs bearing them should be cut off and burned. Trees infested with larvæ during the early part of the year, or those in the immediate vicinity, are perhaps more likely to be chosen by the parent moth for the deposition of her eggs, and such trees at least should be searched if it is not practicable to extend

[1] *Podisus placidus* Uhl., *P. modestus* Dall., and *P. serieventris* Uhl.

the work to the orchard as a whole. This work may be combined with pruning to good advantage, and a lookout should be kept not only for the eggs of this insect but for the eggs and cocoons of other injurious species which pass the winter on the trees.

Practical illustrations of what may be accomplished in collecting the egg masses of this species have recently been reported by Prof. Myron A. Cobb, of the Central State Normal School at Mount Pleasant, Mich. The tent caterpillar was present in unusual numbers in northwestern Michigan during the season of 1913, and egg masses were consequently very much in evidence the following winter (1913–14). Through circulars issued to the rural schools, the school children were interested in the collection of egg masses, with surprisingly successful results. A special "apple-tree tent-caterpillar week" was designated and other means adopted to carry out effectively the campaign against this insect. The total number of egg masses collected through the work of the school children was variously estimated at from one million to several million. A few specific examples may be cited. In Wexford County 250,000 egg masses were reported to have been collected. At Greilickville, 20,443; Bungham School, Grand Traverse County, 17,940. At Elk Rapids the Business Mens' Association offered prizes for the greatest number of egg masses destroyed. This also was done at Old Mission and 65,784 egg masses were collected, the prize going to Carl Ostlind for 11,044 egg masses taken.

Since each egg mass contains on the average some 250 eggs, the benefits from this work may readily be calculated.

There are great possibilities for the accomplishment of much effective work in the control of this and other insect pests by the enlistment of the services of children in rural schools, and the work is a practical application of science for the benefit of agriculture.

DESTROYING THE CATERPILLARS.

Neglect to search out the egg masses during the winter will result in the appearance of the larvæ about the time the trees are putting forth foliage. The nests, at first small, are soon so increased in size as to attract attention. If the caterpillars are destroyed as soon as the small nests are detected, this will prevent further defoliation of the trees, and the rule should be adopted to destroy them promptly as soon as discovered. In this work either of two practices may be adopted, namely, destruction by hand or with a torch.

When in convenient reach, the nests may be torn out with a brush, with gloved hand, or otherwise, and the larvæ crushed on the ground, care being taken to destroy any caterpillars which may have remained on the tree.

The use of a torch to burn out the nests will often be found convenient, especially when these occur in the higher parts of trees. An asbestos torch, such as is advertised by seedsmen, will be satisfactory, or one may be made simply by tying rags to the end of a pole. The asbestos or rags are saturated with kerosene and lighted and the

caterpillars as far as possible cremated. Some caterpillars, however, are likely to escape, falling from the nest upon the application of the torch. In using the torch great care is necessary that no important injury be done the tree; it should not be used in burning out nests except in the smaller branches and twigs, the killing of which would be of no special importance. Nests in the larger limbs should be destroyed by hand, as the use of the torch may kill the bark, resulting in permanent injury.

SPRAYING WITH ARSENICALS.

Tent caterpillars are readily destroyed by arsenicals sprayed on foliage of trees infested by them. Dr. H. T. Fernald's careful experiments and those of Prof. Lowe in determining the amount of poison necessary to kill the caterpillars show that the latter are very sensitive and are killed in from two to three days by the use of Paris green at the rate of 1 pound to 300 or 400 gallons of water.

Orchards or trees sprayed with arsenicals in the spring for the codling moth, cankerworms, or similar insects will be kept practically free from tent caterpillars, and this species rarely requires attention at the hands of the up-to-date commercial fruit grower. It will be troublesome in the scattered trees around the home or in the small orchard which is not regularly sprayed. On such trees the nests will likely be in evidence every spring, and during occasional years the caterpillars may be excessively abundant, completely defoliating the trees.

Even in the small home orchard of a dozen or more trees it will be found highly profitable to adopt a system of spraying which will control not only tent caterpillars but such serious pests as the codling moth, cankerworms, and various bud and leaf feeding insects, and will greatly reduce injury from the curculio.

Any of the arsenical insecticides may be used, as Paris green, Scheele's green, arsenate of lead, etc. The first two are used at the rate of 1 pound to 150 or 200 gallons of water, and the last at the rate of 2 pounds to 50 gallons of water, the milk of lime obtained by slaking 2 or 3 pounds of stone lime being added to neutralize any caustic effect of the arsenical on the foliage. Preferably, however, the poisons should be used in dilute lime-sulphur wash or Bordeaux mixture, thus effecting a combination treatment for insects and fungous diseases. On stone fruits, such as cherry, peach, and plum, arsenicals are likely to cause injury to foliage and must be used with caution. On such trees the arsenate of lead is preferable to the arsenicals, as it is less injurious to foliage, and on all trees sticks much better. In spraying for the tent caterpillar only, applications should be made while the caterpillars are yet small, as these succumb more quickly to poisons than those more nearly full grown, and prompt treatment stops further defoliation of the trees.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 668 MAY 26, 1915

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE SQUASH-VINE BORER.[1]

By F. H. CHITTENDEN,

In Charge of Truck Crop and Stored Product Insect Investigations.

GENERAL APPEARANCE AND METHOD OF WORK.

One of the most troublesome of the many enemies of squashes, pumpkins, and other cucurbits is the squash-vine borer. In many localities this species surpasses all other squash insects in point of injuriousness.

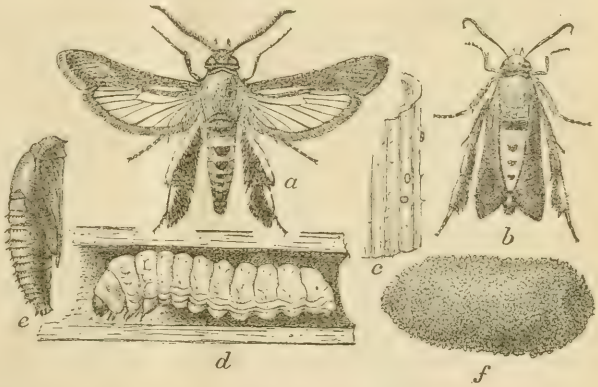

FIG. 1.—Squash-vine borer (*Melittia satyriniformis*): *a*, Male moth; *b*, female, with wings folded at rest; *c*, eggs shown on bit of squash stem; *d*, full-grown larva, *in situ* in vine; *e*, pupa; *f*, pupal cell. All one-third larger than natural size. (Author's illustration.)

Damage is due to the larvæ boring through the stems, causing them to rot at the affected points and become severed from the vine, or so injuring the vine as to cause the leaves to wilt and the plant to die. The presence of the borer feeding within the stem is not apparent at the commencement of the attack, but soon becomes manifest through the presence of the coarse yellowish excrement which it forces from its burrow in the stem and which accumulates on the ground beneath, as well as by the sudden wilting and dying down of the leaves. Wilting occurs soon after the larvæ have made

[1] *Melittia satyriniformis* Hbn.; order Lepidoptera, family Sesiidæ. In early publications this species was generally known as *Melittia ceto*, or *cucurbitæ*.

NOTE.—This bulletin is a revision of Circular No. 38 of the Bureau of Entomology, U. S Department of Agriculture.

considerable growth within. From one to half a dozen or more larvæ inhabit a stem, and often upward of forty individuals have been taken from a single plant; indeed, one grower has stated that he once cut "142 larvæ from a single vine." The larvæ work with great rapidity and in a very short time are able to injure a plant so that no fruit will mature. Injury is most noticeable near the base of the stems, where in course of time the vine becomes severed from the roots and the whole vine dies.

The parent of this insect is a beautiful, medium-sized moth. The forewings are opaque, lustrous olive-brown in color, with metallic green reflections, and expand from less than an inch to nearly an inch and a half. The hindwings are transparent and veined as shown in the accompanying illustration of the male (fig. 1, *a*). The abdomen is conspicuously marked with orange or red, black, and bronze, and the hind legs are fringed with long hairs—red or orange on the outer surface and black inside. The natural position of the moth when at rest is shown by the figure of the female (*b*).

DISTRIBUTION.

As far as known, the squash-vine borer is a native of the Western Hemisphere, and widely distributed and injurious in the United States practically wherever squashes are cultivated. Available records and examination of material in the collection of the U. S. National Museum show that it has a range embracing territory from the New England States and Canada, in the north, to the Gulf States southward, and westward to the region beyond the Missouri River, which comprises the major portion of the Carolinian and Austroriparian areas of the Upper and Lower Austral life zones and a portion also of the Transition zone. Injury has been observed to be particularly severe in recent years on Long Island and in New Jersey, Delaware, Maryland, Virginia, and the District of Columbia, in the East, and in Kansas and Nebraska in the West. Other States in which injury has been noted include Maine, Massachusetts, Connecticut, Rhode Island, Georgia, Alabama, Mississippi, Louisiana, Iowa, and Michigan. It is evidently of tropical origin, and occurs in Mexico, where it is also widely distributed, and in Guatemala, Panama, Venezuela, Argentina, and the lower Amazon.

FOOD HABITS.

The vines of squash and pumpkin form the chief food supply of this insect, but occasionally it attacks also the gourd, muskmelon, and cucumber. It does not, however, in the writer's experience, infest melons and cucumbers when the other preferred crops are available. The larvæ bore through the stems from the roots to the base of and even through the leaf stalks, and young larvæ may be found even in

the larger veins, into which they bore when the eggs have been placed in such locations, and often attack the fruit. They also penetrate gourds so hard that it is difficult to cut into them with a sharp knife. Larvæ have been observed on the wild balsam apple,[1] which is probably a natural food plant.

Injury is greatest to Hubbard, marrow cymlings, and other late varieties of squash, and is apt to be more acutely felt in small gardens than where crops are grown for market. Even if the plant survives attack it may not bear fruit, and often the grower loses a large proportion of his crop year after year. Not infrequently entire crops are destroyed, and still more frequently every plant in a field is attacked freely.

NATURAL HISTORY.

This species is injurious only in the larval form. Although the larvæ are familiar objects to squash growers, the moths are not generally recognized as the parents of these pernicious borers.

The moths, unlike most others, fly only during the daytime and in the heat of the day. Toward twilight they become less active and may be seen sitting quietly on the leaves of their host plants. Both when in flight and when at rest the moths are singularly wasp-like in appearance.

TIME OF APPEARANCE OF THE MOTH.

Approximately it may be stated that the moth appears as soon as the vines are sufficiently advanced to serve for oviposition and the subsequent subsistence of the borer larvæ within their stems. Indications are that as far south as the District of Columbia the moths make their first appearance in the field some time in May, or, at least, early in June, as larvæ nearly matured have been found by the middle of July. In New Jersey, according to Dr. J. B. Smith, the moths are abroad at or soon after the beginning of June; on Long Island, from the middle to the last of June. In Massachusetts, according to Harris, they appear about the plants the second week in July. We thus have considerable variation in time of earliest appearance, dependent upon season and locality—a variation to be expected in a species of so wide a range.

THE EGG AND OVIPOSITION.

The eggs, which are oval and dull red in color, are laid upon all parts of a plant, from the roots to the buds and petioles, but chiefly along the stems, although in some varieties of squash, it is said, nearer the base of the stem than otherwise. Oviposition is very rapid, the moth flitting from hill to hill, leaving an egg in each. A single moth may lay as many as 212 eggs. The eggs hatch in from six to fifteen days after they are deposited, and the larvæ are said to attain full

[1] *Echinocystis lobata.*

growth four or more weeks later. This period will undoubtedly vary in different temperatures, according to the season of the year when oviposition takes place.

Eggs are shown a little larger than natural at *c* of figure 1, and much magnified at *a* and *b* of figure 2, *c* showing the sculpture.

THE LARVA.

The larva is a soft, whitish, grublike caterpillar of nearly cylindrical form, with a small dark head and a few very sparse hairs on each segment. Larvæ in the earlier stages of growth are illustrated by *d*, *e*, and *f* of figure 2. A full-grown larva is shown in profile within an open stem at figure 1, *d*, and the head and first two thoracic segments appear in figure 2 at *g*. Mature larvæ measure about an inch (25 mm.) in length. In the District of Columbia full-grown larvæ, as already observed, occur as early as July 16; in New Jersey, later in July, and are to be found upon the vines in different stages in October; at Washington, as late as the second week of November.

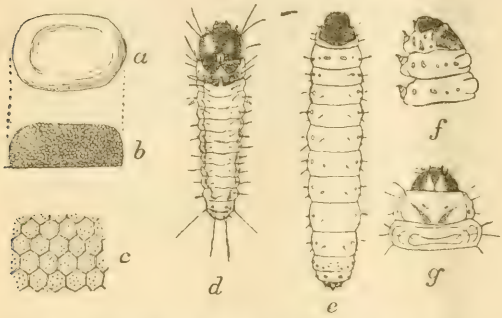

FIG. 2.—Squash-vine borer: *a*, Egg as seen from above; *b*, same from the side, showing sculpture; *c*, sculpture of egg greatly enlarged; *d*, newly hatched larva; *e*, half-grown larva; *f*, head of same from side; *g*, head of mature larva from above. *a*, *b*, and *c*, Much enlarged; *d*, *e*, *f*, and *g*, less enlarged. (Author's illustration.)

After attaining maturity the larvæ desert the stems and enter the earth, burying themselves to the depth of 1 or 2 inches, and form their cocoons, in which they transform to pupæ. The cocoon (fig. 1, *f*) is constructed of silk and coated externally with fine particles of earth, which adhere on account of some gummy secretion of the larva.

THE PUPA.

The pupa, or chrysalis (shown in profile at *e*, fig. 1), measures about ⅝ inch (16 mm.) in length. It is shining mahogany brown in color, and its head is ornamented in front just above and between the eyes with a hornlike process. By means of this the pupa cuts its way out of one end of its cocoon and by the aid of the abdominal hooklike spines forces itself to the surface of the earth before transforming to adult.

NUMBER OF GENERATIONS.

The question of the number of generations produced annually in localities of different temperatures which this insect inhabits has been solved by actual observation, the results serving to indicate that it is practically single-brooded on Long Island and northward; that there is a tendency to two broods in New Jersey, the moths in

exceptional cases completing their transformations late in August or September; that in the latitude of the District of Columbia the species is partially double-brooded, a larger portion of the moths, we may assume, developing as a second generation here than in New Jersey; and that in the Gulf States this species is undoubtedly fully two-brooded.

PREVENTIVE AND REMEDIAL MEASURES.

This borer is an exceptionally difficult insect to control, as ordinary insecticides are of no value after the insect has once entered the vines, and repellents are also practically useless. We are, therefore, dependent upon cultural methods for relief.

Knowing that the insect passes the winter in the fields which it has ravaged, it should be superfluous to caution growers against planting squashes in the same ground in successive years.

EARLY SQUASHES AS TRAPS.

Good results have been obtained by planting as a trap crop and as early as possible a few summer squashes, such as crooknecks and early cymlings, before and between rows of the main crop of late varieties. The summer squashes attract the insects in such numbers as to leave a smaller number to deal with upon the late or main crop. As soon as the early crop is gathered, or earlier if the ground is needed for the main crop, the vines are promptly raked up and burned to destroy all eggs and larvæ which they may harbor, and the same treatment is followed after gathering the late varieties. This method, according to the late Dr. J. B. Smith, has proved profitable where used in New Jersey and should produce good results farther north. Southward, where two well-defined broods appear, it might not be so productive of good, but it should be given a thorough test.

FALL HARROWING AND DEEP SPRING PLOWING.

Experiments conducted by Mr. F. A. Sirrine, of the New York Agricultural Experiment Station at Geneva, N. Y., show that this species can be greatly reduced by lightly harrowing the surface of infested squash fields in the fall so as to bring the cocoons of the vine borer to the surface, where they will be exposed to the elements, and then plowing in the spring to a uniform depth of at least 6 inches, so that the adults will not be able to issue.

OTHER CULTURAL METHODS.

When the vines have attained some length parts of them should be covered over with earth, so that secondary roots will be sent out to support the plants in case the main root is injured by the borer. Keeping the plants in good condition, free from other insects and from disease, and well nourished with the assistance of manure or

other fertilizer if necessary, will also aid the plants to withstand borer attack. When vines are so badly infested as to be incapable of bearing fruit they usually die at once, and they should then be promptly taken out and burned. The old vines should also be destroyed as soon as the crop is made.

CUTTING OUT THE BORERS.

The old-time remedy of cutting the borers out of the vines, although laborious, is useful, and about the only method open for employment after they have entered the vines. As several individuals often infest a single vine, it is best to cut longitudinally, so as not to sever the vine from the root stalk. If the wound made by cutting be afterwards covered with moist soil it will assist it to heal. The location of the borer in the vine can be readily detected by the accumulation of its yellow "frass" or excrement at the point where it is working, and which is kept open for the extrusion of this matter.

CAPTURING THE MOTHS.

This species may be held in partial subjection by keeping a sharp lookout for the parent moths, which are readily seen and not difficult of capture toward dusk or in the cool of the morning, when they are comparatively inactive. The female may then be easily caught, just as she alights on a vine for oviposition. Several persons, including the writer, can vouch for this statement.

SUMMARY.

If the grower would make certain of securing a good crop in localities where this and other enemies of the squash occur in their most destructive abundance, it will be necessary for protection against this borer to observe most of the following precautions, and, if possible, secure the cooperation of his neighbors in their observance:

(1) Not to plant in or near infested ground.

(2) To plant early varieties for the protection of late squashes.

(3) To harrow infested fields lightly in fall and plow deeply in spring, to prevent the moths from issuing.

(4) To encourage the growth of secondary roots by covering the stems with earth.

(5) To destroy dead vines and old plants as soon as the crop is made.

(6) To keep the plants in vigorous condition, free from other insects and disease.

(7) To cut out such borers as may succeed in entering the vines in spite of the employment of other remedial measures.

(8) The capture of the moths before egg deposition is advisable.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 671 MAY 26, 1915

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

HARVEST MITES, OR "CHIGGERS."

By F. H. CHITTENDEN,

In Charge of Truck Crop and Stored Product Insect Investigations.

INTRODUCTION.

Residents of the South and of the more southern portions of many of the Central States, and especially visitors to these sections, are often subject to great annoyance due to the attacks of minute creatures popularly known as "chiggers" [1] and "red bugs," and incorrectly as ticks. These creatures occur in blackberry bushes, shrubbery, grass, and weeds, and persons walking or sitting down in such localities are liable to attack. "Chiggers" usually enter the skin near the shoe tops or at points below the knees, but sometimes they are jarred from bushes or small trees on to the neck and other exposed portions. Their habit of burrowing under the skin is not normal and brings about their death. Nevertheless the inflammation thus caused may become very painful, and where many of the creatures have attacked a person this may frequently lead to fever or other disagreeable consequences. The desire to scratch the affected spots is very strong, and scratching with the fingernails may easily abrade the skin and might communicate infec-

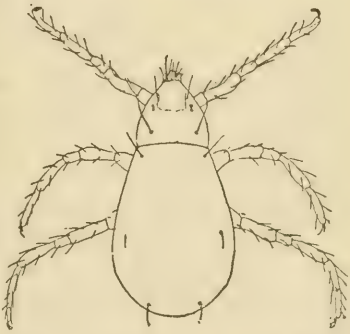

FIG. 1.—*Trombidium:* sp.: Larva, highly magnified. (From Banks.)

[1] The name "chigger" or "jigger" is evidently a corruption of chigoe, the pernicious sand flea (*Sarcopsylla penetrans* L.) of tropical America, a true flea, which crawls under the toe nails of man, producing painful sores which may result seriously if neglected.

NOTE.—This bulletin, which is a reprint, with revision, of Circular No. 77 of the Bureau of Entomology, U. S. Department of Agriculture, treats of the harvest mite and means for the protection and relief of human beings subject to its attack, together with methods of eradication. It will be of interest wherever this pest is troublesome.

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tion from the nails or other outside sources. Children, and especially those who begin to go barefoot in grassy places in June to September, are great sufferers from this minute enemy.

WHAT "CHIGGERS" ARE.

These pests are the larval or six-legged forms of harvest mites of the genus Trombidium, the adults of which have eight legs. For present purposes we may consider the harvest mites as a class. In figures 1 and 2 illustrations of some common forms are furnished. The larval harvest mites are of microscopic size, blood red, and shaped somewhat like a common tick, being nearly as broad in front as behind. They belong to the order Acarina and are not true insects (Hexapoda), but are members of a distinct class (Arachnida) along with ticks, spiders, and the like. The parent mites are predaceous on true insects. As early as 1834 Mr. A. L. Dugès[1] made observations on these mites, which, as previously stated, have six legs in the immature or parasitic stage, while the adults have eight. The adults are of different shades of red and are quite visible. Many persons are familiar with the appearance of the young of certain species, as they occur on the under surface of the bodies of grasshoppers and harvest spiders or "daddy-long-legs" (Phalangiidæ) and under the wings of the house fly. Just what species of harvest mites are troublesome to man in the United States is not known, but one of them, perhaps the commonest, is referred to in literature as "*Leptus*" *irritans* Riley.[2]

FIG. 2.—*Leptus americanus* at left; *Leptus irritans* at right. Highly magnified, dots under anal extremity indicating natural size. (After Riley.)

SYMPTOMS AND MANNER OF ATTACK.

Soon after the harvest mite burrows under the human skin a small red spot appears (evidently the mite itself gorged with human blood),

[1] Dugès, Ant. Recherches sur l'ordre des Acariens en general et la famille des Trombidiés en particulier. *In* Ann. Sci. Nat. Zool., t. 1, ser. 2, art. 1, p. 36, 1834; see also Megnin, P., Memoire sur les Metamorposes des Acariens en general et en particulier sur celles des Trombidions. L. c., t. 4, sér. 6, art. 5, p. 1–20. 1876; and Murray, Andrew, Economic Entomology, Aptera, p. 129–133, London, 1877.

[2] Riley, C. V. Poisonous insects, p. 745, fig. 2980, New York. 1887. (Extracted from Reference Handbook of the Medical Sciences, v. 5.)

Leptus is a genus founded on the larval Trombidium. Those who may desire further information in regard to the structure of the adult may consult Banks, Nathan: "A treatise on the Acarina, or mites." (*In* Proc. U. S. Nat. Mus., v. 28, p. 30, 31, 1904.)

after which the surrounding surface becomes congested, the affected area spreading until it is from less than a fourth to a half or three-fourths of an inch in diameter. This congestion may manifest itself within less than an hour after exposure or may not be apparent for 12 hours or so, the fever being at its height usually on the second day. The symptoms are apt to be first noticed when the sufferer has removed his clothing at night, or upon awakening from sleep. It sometimes happens that there is little irritation until some time after exposure, but with most persons susceptible to the poisonous effects of these mites irritation is first experienced on the second day. The feverish appearance of the afflicted skin area varies according to the susceptibility of the person attacked. Children dwelling or sojourning in mite-infested localities suffer greatly from these pests, experiencing more severe annoyance than adults, and young women as a rule suffer more than older persons. People with thin, delicate skin and florid complexion are most afflicted by the mites, and with them the congested red spots are proportionately larger and more inflamed and irritating.

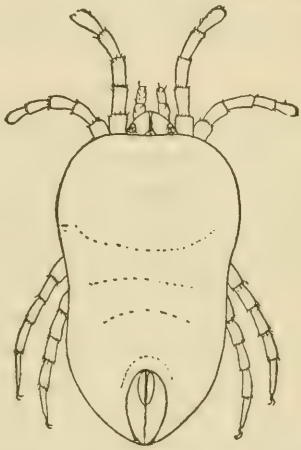

FIG. 3.—*Trombidium* sp.: Adult, highly magnified. (From Banks.)

Many persons, however, as, for example, permanent residents of infested regions, and particularly farm laborers, seem to be practically proof against the toxic effects of harvest mites and go with impunity into places overrun with them. This immunity to poisoning is obviously due to two causes: (1) To outdoor work which toughens the person's skin, especially such portions of the arms and legs as are much exposed to the sun and weather; and (2) to inoculations, due to frequent infection.

The inflamed spots due to the presence of the mites under the human cuticle are often diagnosed as hives, nettle rash, urticaria, or the "wheals," and resemble closely those produced on many persons by the "bites" of fleas and some mosquitoes, but on the second or third day each of the mite-infested areas is usually found surmounted at the middle by a minute vesicle or water blister. This is obviously the most important characteristic of harvest-mite attack. After the subsiding of the inflammation and itching, which takes place in a few days, a small scale or scab frequently forms, leaving on some persons a scar which does not wholly disappear in extreme cases for weeks. The mites naturally attack first those portions of the body which are most exposed—those nearest the ground. They crawl into the

stockings and penetrate the skin about the ankles, frequently below the shoe tops, and are usually found most numerous below the knee. According to the late Dr. John Hamilton, a physician as well as entomologist, the harvest mites enter the larger sweat tubes or pores of the skin, and as these tubes are very tortuous, the progress of the mites is necessarily slow, from 18 to 36 hours being required for them to reach the end. When the lesions caused by these mites are unusually numerous, the sufferer becomes feverish, and sleep is much disturbed. Sometimes the afflicted one becomes frantic and lacerates his flesh by too vigorous and frequent scratching. Erysipelas is known to follow severe attacks, and death resulting from blood poisoning is recorded. These more serious results of infestation are, however, exceptional and, as with the fatalities which in rare cases follow the ordinarily merely painful or annoying "bites" of many insects, undoubtedly point to an impurity of the blood.

HABITAT.

Harvest mites are most abundant in damp locations, along the borders of streams and other bodies of water, and on the edges of forest and woodland. They occur also on trees and shrubbery, evidently infesting the lower surface of the leaves, from which they drop off when these are rudely shaken, and find lodgment on the neck or other exposed parts of the body. Riley describes "*Leptus americanus*" as affecting chiefly the scalp and armpits. In places infested by harvest mites it is a matter of danger to sit down or lie in the grass and herbage for any length of time, as the mites will then have easy access to almost any portion of the body. As a rule these creatures appear to be dependent on the shade and not to live in the direct sunlight, but some forms occur in sunny locations.

These mites are most abundant and troublesome in the Tropics, and become less numerous as we go northward. They are generally distributed in the Gulf States, up the Mississippi River to Missouri and Illinois, and through the Atlantic Coast States to northern New Jersey. They appear to be unknown in New York and New England, or north of latitude 40° in the East.

Trouble from chiggers has also been reported in portions of Tennessee and practically throughout the State of Ohio, because we have record of injury as far north as Sandusky, which is on Lake Erie, Lima, in the northern part of the State, Cincinnati, and Columbus. Reports that these creatures have also been found in other localities may and may not be true at the same time, since with the cultivation of the soil and the destruction of wild bushes and other places of harbor they have practically disappeared. There are reports also of the occurrence of chiggers at Horicon, Wis., and La Fayette, Ind., in Minnesota, and at Belvidere, S. Dak.

Several reports have been received of a plague of these mites in the vicinity of Chicago, Ill., showing similar distribution in that State. Chiggers are well distributed in Kansas, and reports would indicate similar conditions in Indiana and portions of Iowa.

Harvest mites are well known in England and Scotland under this name and as "gooseberry bugs." On the Continent of Europe, also, they are abundant, especially in Belgium and the Netherlands, in parts of Germany, and in France. Indeed, in some of these countries they have at times caused considerable annoyance to the peasantry, whom they have hindered or prevented in the harvesting of certain crops. The mites are troublesome, too, in tropical America, in the West Indies, and in Japan.

LIFE HISTORY.

The life history of a harvest mite, as related by Mr. Nathan Banks, is substantially as follows: The female lays her eggs in or upon the ground, sometimes to the number of 400 in one place. The eggs are usually brown and spherical and have been considered by some early writers as fungi. The chorion or outer skin splits soon after the eggs are deposited, dividing the eggs into halves and exposing the pale vitelline membrane. The larva when hatched is circular or ovoid in outline, and each of its three pairs of legs is tipped with two or three prominent claws. After the larva has become attached to its insect host it elongates and becomes swollen with food. When full fed it drops off, seeks a convenient shelter, and gradually changes in shape without molting. The new parts are formed under the larval skin, which after a few weeks cracks and discloses the adult Trombidium. The mature harvest mite is predaceous, wandering about and feeding on aphides, small caterpillars, and, in the case of one species, on the eggs of grasshoppers or locusts. It hibernates in the soil or in other sheltered locations and in the spring deposits its eggs. There appears to be a single generation produced each year. Only a few forms have been reared. The larva of one occurs commonly on the house fly in autumn.

REMEDIES.

As harvest-mite infestation is usually contracted by walking or working among blackberry and other shrubbery which harbors them, or by walking, sitting, or lying among grasses or similar herbage along streams or pools, on the edges of marshes, or under trees near such places, it is obvious that the best means of prevention is the avoidance of exposure by susceptible persons. If, however, a bath is taken in hot water, or water containing salt or strong soap, within a few hours after exposure, no ill effects will be experienced. After a longer exposure a bath has practically no effect, and direct remedies are necessary.

Sulphur is a sovereign remedy for mites and is the best preventive of attack. When exposure is unavoidable and where vegetation is not more than 2 or 3 feet high, a sure preventive is found in sifting flowers of sulphur into the underclothes from a little above the knee downward and into the shoes and stockings, or it may be rubbed over legs and ankles. Naphthalene has been successfully used in the same manner. While the sulphur, being inodorous and perfectly effective, is undoubtedly preferable against harvest mites alone, naphthalene is a safeguard against various forms of man-infesting tropical insect pests. Vaseline, pure or mixed with sulphur, will serve the same purpose, but is not so agreeable on account of its oily nature and the certainty of its soiling the clothing.

For most localities these precautions are to be observed through the months of July, August, and a part of September. The mites are seldom bothersome in early June or as late as October, but in exceptionally warm seasons they are apt to be encountered in both months.

If exposure has been unwittingly incurred or precautions have been neglected and the characteristic irritation has set in, warning the patient of trouble to come, a counter-irritant or cooling lotion should be applied directly to the affected parts. For this purpose moderately strong ammonia, applied when the symptoms are first manifest, has offered the best results, and the writer recommends it above all other direct remedies. Bicarbonate of soda, or common cooking soda or saleratus, may be substituted in supersaturated solution. Similar alkaline solutions would probably also serve in counteracting the insect poison, which is acid. These substances should be applied liberally until the irritation subsides. Some persons have testified to the value of a 10 per cent dilution of carbolic acid. Alcohol, camphor, essence of peppermint, and similar preparations are very "cooling," but afford, as a rule, only temporary relief. A dilute tincture of iodine or collodion applied lightly to the affected parts is a good remedy in case of severe suffering. The latter acts by protecting the "sore" spots from the air.

DESTRUCTION OF THE MITES IN THE FIELD.

Much complaint has been made of the presence of harvest mites on lawns and in vegetation in country grounds and along pathways and roadsides, and information has been solicited by many, including officers of country clubs and the like, for methods of eliminating the mites from such locations. This can be accomplished by keeping the grass, weeds, and useless herbage mowed as closely as feasible, so as to expose the mites to the sun. In some cases this can be facilitated by dusting the grass and other plants, after cutting, with flowers of sulphur or by spraying with dilute kerosene emulsion in

which sulphur has been mixed. Grasses on the borders of ponds frequented by cattle, wild blackberry bushes, and similar plants should also be cut down and destroyed in the vicinity of houses and where children and older persons are liable to mite infestation by passing through them. Well-cultivated fields kept free from weeds are not infested with "chiggers," and in the course of time, perhaps a year or two, the measures prescribed, if carefully carried out in grassy locations, should also entirely free these from the pests.

In severely chigger-infested tracts of, say, 400 acres, where there are no bushes or shrubs of value, cattle may be inadequate, and correspondents and others have stated as their experience that after turning sheep into the fields the chiggers were destroyed. Undoubtedly this was due largely to the fact that the sheep kept the grass more closely cropped than cattle would have done, but there is also a belief that the chiggers ascend the legs of the sheep and that the oil or lanoline of the wool is responsible for their death. Hence it is believed that sheep turned into large tracts such as described would accomplish the eradication of the mites more thoroughly and in a shorter space of time than would perhaps any other domestic animal, even including goats, which might be used in some cases.

For the eradication of chiggers on the grounds of wealthy private individuals and clubs the application of ordinary flowers of sulphur might be both cheaply and thoroughly made by the use of one of the dust blowers used for dusting potatoes with Paris green, or by one of the sulphur dusters used for spraying orange trees for the red spider in California. These sprayers are capable of throwing a fan-shaped discharge about 8 feet wide and effect very even and thorough distribution. The cost of application, allowing 50 pounds of sulphur per acre, should be from $1 to $1.50 per acre, and since with one man and a team 30 to 40 acres a day may be covered, the expense of application is not great. Such a duster costs from $65 to $80.

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WASHINGTON, D. C. 674 JULY 8, 1915.

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

CONTROL OF THE CITRUS THRIPS IN CALIFORNIA AND ARIZONA.

By J. R. HORTON, *Scientific Assistant, Tropical and Subtropical Fruit Insect Investigations.*

INTRODUCTION.

The citrus thrips,[1] a minute orange-yellow insect, has in the past few years caused extensive damage to citrus fruits in the San Joaquin Valley of California and also occasioned considerable injury in southern California and Arizona orange groves.

The nature and extent of the injury caused by this insect and its life history and habits were carefully studied, and extensive experiments for its control were conducted by the writer during the period from 1910 to 1912. It is the purpose of the present paper to give briefly the practical control measures resulting from these studies.

INJURY.

The citrus thrips is a sucking insect feeding on the plant juices of the leaves, the fruit rind, and the bark of tender stems, in much the same manner as the mosquito draws its food from its victims. For this reason the insect can not be killed by stomach poisons sprayed on the plant, but must be controlled by sprays that kill by contact.

The injury caused by the citrus thrips begins with the seedling orange tree. The leaves are scarred and distorted, and to a certain extent the stock is devitalized. When the seed stock is budded and the foliage of the seedling trimmed off, the thrips attacks the bud. Nursery buds will make a fine, luxuriant growth of 2 or 3 feet in a

[1] (*Euthrips*) *Scirtothrips citri* Moulton; order Thysanoptera, family Thripidæ.

NOTE.—This bulletin is of interest to the citrus growers of the Pacific coast and the Southwest.

season if properly sprayed to protect them from thrips. On the other hand, many nursery trees have the leaves and stems so badly scarred and twisted as to give them a blighted, unsightly appearance, and are so retarded in growth that they must be held in the nursery for a year or more beyond the proper time for sale in order to meet the size requirements, thus decreasing the nurseryman's profit by the cost of the extra care. It sometimes happens that this class of stock is sold along with better trees, and the thrips injury continues for

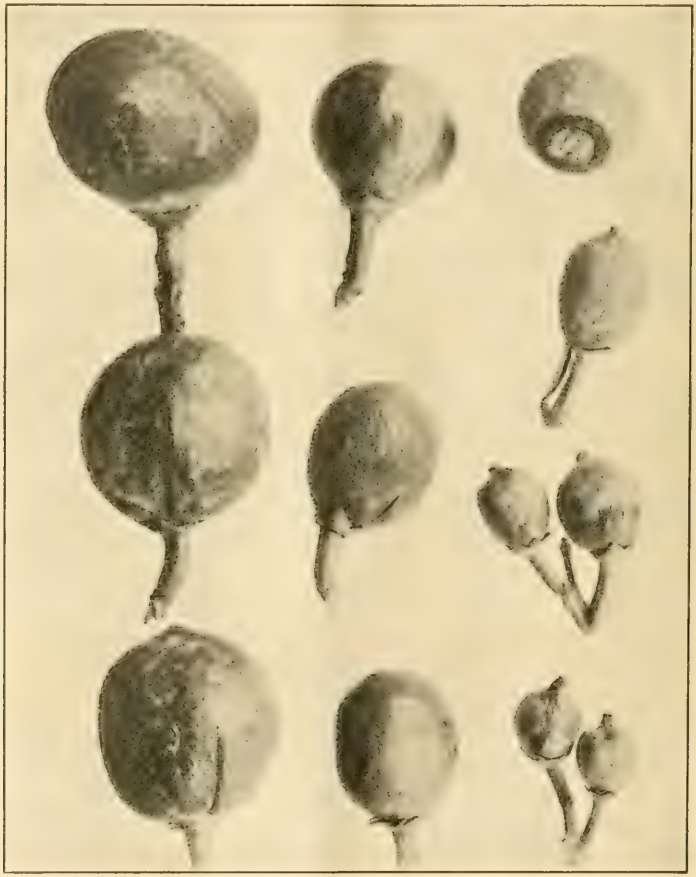

FIG. 1.—Injury to young oranges by the citrus thrips (*Scirtothrips citri*). (Original.)

several years in the orchard. The writer knows of 5-year-old and 7-year-old groves in the foothills of Tulare County which have been held back, principally by thrips, to such an extent that the trees are no larger than 3 and 5 year trees in less infested situations. From the general appearance of such trees it seems evident that they will never attain the size and bearing capacity of trees which have escaped severe thrips infestation in the nursery and during their early years in the orchard.

As the young fruit appears it in turn is attacked (fig. 1), and its market value at maturity is much reduced by the enlarged feeding scars and scabbing (fig. 2). A larger percentage of small-sized fruits than ordinarily develop results, and there is a total loss, as the result of early and severe scabbing, of a proportion of the fruit. To calculate the damage caused by the insect in reducing the grade of the fruit, it is necessary to know the system of grading and the relative market value of the grades. Three packs are usually made in California packing houses at the time of this writing, these packs or grades being variously designated as "Fancy," "Choice," and "Standard"; "Extra Fancy,"

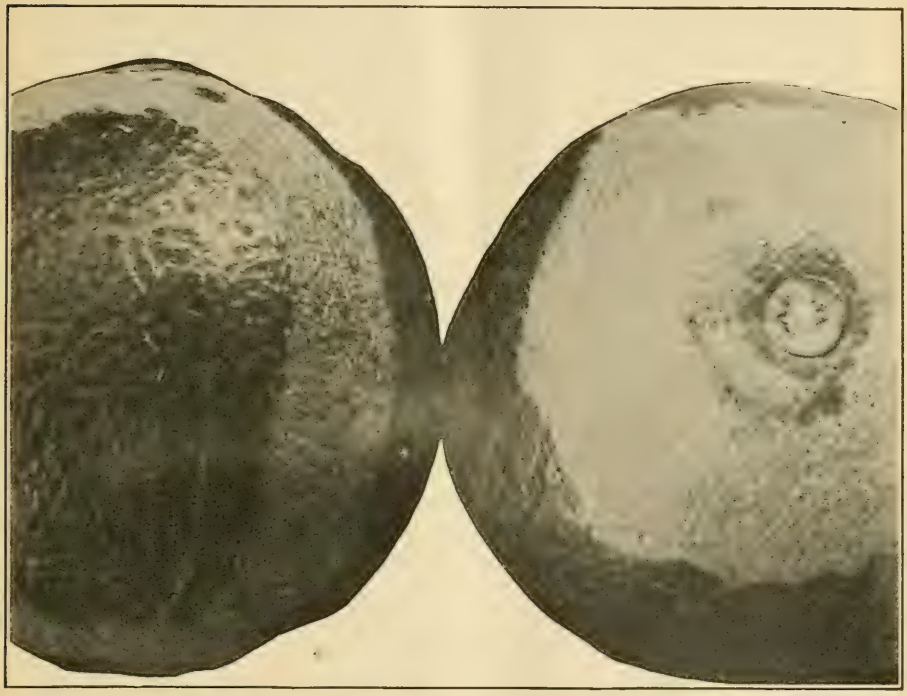

FIG. 2.—Mature oranges, showing injury by citrus thrips. (Original.)

"Fancy," and "Choice"; or "Extra Choice," "Choice," and "Standard." Whatever the terms used there is usually little difference in the quality of fruit of corresponding grades at the different packing houses. In other cases only two divisions are made, the first grade generally being designated as "Orchard Run" and the second or lower grade as "Standard." Under the latter system the quality of the fruit composing the first grade is about the same as would be obtained by placing together all the fruit of the first and second grades of the three-grade pack. Statistics upon the quantity of fruit shipped from the entire San Joaquin Valley and the prices received for it are not available, but from Lindsay and its tributaries 1,525 carloads of navel

oranges were shipped in 1911. The approximate average number of boxes of fruit to the car is 390, making 594,750 boxes for the season's shipment. From examination of thousands of oranges in the field, throughout the district and in many groves, it was calculated that 34 per cent of all the fruit would be classed as first grade so far as thrips injury was concerned, 43 per cent as second grade, and 23 per cent as third grade. Returns received by different packing houses on a total of 358,000 boxes of navels of all grades for the season indicated the following average differences in price per box between the different grades. First-grade fruit averaged 37 cents more per box than that of second grade; the latter 28 cents more than that of third. Fruit shipped in only two grades gave an average difference of 51 cents per box in favor of the first grade. It may be seen from the foregoing data that 43 per cent, or 255,742 boxes, of the Lindsay fruit was reduced to second grade at a loss of 37 cents per box, or $94,624.54; 23 per cent was reduced to third grade at a loss of 65 cents per box, or an additional $88,914.80. There was thus a total loss for the Lindsay district alone of approximately $183,539.34 in the season of 1911 from grade reduction caused by thrips.

SUMMARY OF SEASONAL HISTORY.

In seasons such as 1911, adult citrus thrips first appear in April and increase rapidly during April and May, during which time the insects are congregated largely on the fruit and foliage of the orange. During part of June, July, and August the adults leave the toughening fruit and leaves of the orange and disperse over miscellaneous food plants, and it is during this period of wider separation that mating and oviposition are somewhat checked. In August and September there is a series of flights back to the late summer growths of the orange, where the insects concentrate in large numbers, mating and actively depositing the eggs which produce the insects of the following spring.

The citrus thrips begins to disappear about the middle of October, and after December practically none can be found. There are generally a few larvæ and adults in places on the trees until the early part of January, at which time they disappear completely. The eggs which are deposited in the stems and leaves of the orange in the fall mostly pass the winter successfully, hatching during the ensuing March, April, and May. The seasonal activities of the citrus thrips, as related to orange blossoming, growth periods, and spraying are summarized graphically in figure 3.

SUMMARY OF LIFE HISTORY.

There is a tendency on the part of the citrus thrips to breed throughout the year. All stages of the insect are found on the trees throughout November and December. Larvæ, pupæ, and adults gradually

die off as the weather grows colder, until by the middle of January all have disappeared. The winter is passed only in the egg stage. Eggs deposited in the leaves and stems, mostly during late August, September, and October, hatch and the larvæ appear in March, April, and May.

The average duration of the egg stage of summer generations varies from 10 to 18.8 days during May and June, 6.8 to 8.5 days in July and August, and 17 to 18.8 days in September and October.

The average larval stage varies from 6.6 to 13.7 days during April and May, 4.2 to 9 days from June to August, and 6.7 to 11.2 days in September and October.

The average pupal stage varies from 4.7 to 13 days during April and May, 2.8 to 5.1 days from June to August, and 5 to 19.9 days from September to November.

Pupation takes place in crevices on the tree trunk, in dead leaves and rubbish under the trees, and under clods and particles of trash

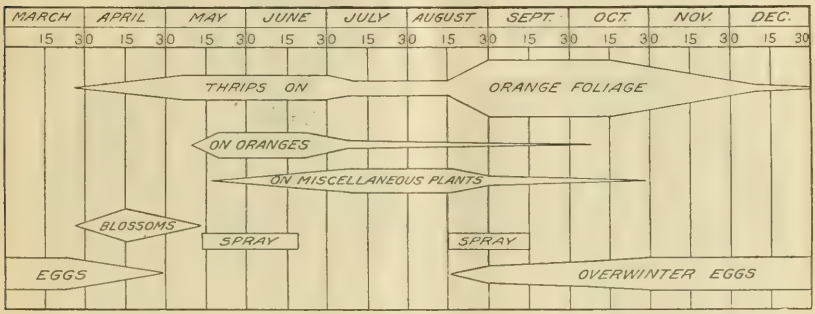

FIG. 3.—Graphic illustration of the seasonal activities of the citrus thrips as related to blossoming and later growth periods of the orange, and indicating also the spray periods. (Original.)

on the ground, but never in the ground. The pupa is naked, does not construct a cell, and is at all times capable of locomotion.

The average duration of adult life is from 25 to 35 days, with extreme instances running to from 46 to 49 days. Adults can live from 2 to 6 days only without food.

The number of generations in a season will depend upon the character of the season. An early, warm spring followed by a prolonged, hot summer may result in the production of eight or more generations. In seasons such as 1911, six full generations may be expected between the middle of April and the first of November. For purposes of control the citrus thrips must be treated as an insect having only a single generation a season, and with an egg-laying period extending from April to November.

REMEDIES FOR THE CITRUS THRIPS.

Certain measures against the citrus thrips have been persistently recommended in spite of abundant evidence of their inapplicability. These are usually directed against the pupal stage and consist in the application of insecticides to the soil, breaking the soil up fine to destroy the insects supposedly pupating there, and burning dead leaves and trash, which accumulate under the trees, to destroy the pupæ. These methods are worthless for the reason that the thrips

FIG. 4.—Resin-wash injury to half-grown oranges sprayed for the citrus thrips. (Original.)

do not go into the soil at all, and only a varying and often small percentage of them pupate in the trash. Fumigation with hydrocyanic-acid gas will reach and kill only the larvæ and a small number of adults, and is accordingly too expensive to use. Distillate-oil emulsions and proprietary emulsions containing distillate, even when used as weak as 2 per cent, stain the ripe oranges, and are otherwise so injurious that it is considered unsafe to use them. Commercial lime-sulphur is not noticeably injurious when used at less than 1 part to 28 parts of water. Resin wash can not be safely used on orange trees at any strength. Where the resin mixture comes into contact with the fruit the epidermal cells are killed and

a shallow brown scab is formed. (Fig. 4.) Where the liquid collects in large drops it forms a thick, amber-to-black scab which does not slough off readily. About 20 per cent of the fruit at picking time was thrown into the lowest grade owing to scabbing through the use of the weakest resin wash.

There is only one cheap and effective method of citrus-thrips control, viz, the application at high pressure of contact insecticides, preferably mixtures containing sulphur in solution. Sulphur mixtures at the proper strength have given uniformly high killing results and have thus left no doubt as to their insecticidal power over this species. They further show a more or less marked tendency to repel the insects and prevent rapid reinfestation of sprayed trees.

SPRAY MIXTURES AND DILUTIONS.

Of the large number of combinations of insecticides tested, the following have given the best results, and any of the mixtures here recommended may be relied upon to do good work:

1. *Commercial lime-sulphur.*—If the lime-sulphur is of a density of 36 degrees on the Baumé scale, dilute 1 gallon with 56 gallons of water; if of a density of 33 degrees Baumé, dilute 1 gallon with 50 gallons of water.

2. *Sulphur-soda solution.*—Two gallons of the stock solution, prepared as described on page 8, diluted with 25 gallons of water.

3. *Commercial lime-sulphur and blackleaf tobacco extract (40 per cent nicotine sulphate).*—Dilute 1 part of the commercial lime-sulphur, if 34 to 36 degrees Baumé, with 86 parts of water; if 30 to 33 degrees Baumé, with 75 parts of water. Then add 1 part of the tobacco extract to 1,000 parts of the lime-sulphur diluted as above.

4. *Blackleaf tobacco extract (40 per cent nicotine sulphate).*—Dilute 1 part with 800 parts of water.

COMMERCIAL LIME-SULPHUR.

The commercial lime-sulphur, diluted with water and without the addition of other chemicals, is preferred to any of the other insecticides because of its cheapness and convenience in mixing. Very good grades of lime-sulphur can be purchased in the market at a reasonable price, and since the preparation of this product requires care and experience, and as it must be made fresh each time or special precautions taken to store it in air-tight containers, its home manufacture is not advised. When necessary to carry the market product over a season it is essential to protect it absolutely from the air, as it rapidly loses its insecticidal power when exposed through leaky barrels or an open bung.

SULPHUR-SODA SOLUTION.

Another mixture containing sulphur as the most important ingredient is made by dissolving sulphur with the aid of caustic soda, according to the directions given below. This mixture, though

practically as effective in controlling the citrus thrips as lime-sulphur, can not be purchased ready-made and is therefore less convenient to handle. Furthermore, at the present writing it costs just as much per dilute gallon as the factory-made lime-sulphur.

The sulphur-soda stock solution is prepared as follows:

Powdered sulphur	30 pounds.
Powdered caustic soda (98 per cent)	15 pounds.
Water to make	30 gallons.

The sulphur is made into a paste with water, and while the mixture is being constantly stirred the soda is added in sufficient quantity to start boiling. As boiling becomes violent a little water is added to retard it. When the sulphur has all been taken into solution enough water should be added to bring the stock solution up to 30 gallons. If made according to the foregoing directions the final product will be a clear, amber-colored liquid much resembling good commercial lime-sulphur.

PLAIN TOBACCO EXTRACTS.

Tests with plain tobacco extracts without the addition of lime-sulphur or other preparations have given very good results when the tobacco has been used at sufficient strength. Tobacco extract containing 40 per cent nicotine used at the rate of 1 part to 800 parts, liquid measure, of water is quite satisfactory; when diluted at the rate of 1 part to 1,600 parts water, however, its efficiency is noticeably lowered. It can not be recommended for this work in solution weaker than 1 to 1,000, and should preferably be used at the rate of 1 to 800. The commercial tobacco extract containing a high percentage of nicotine sulphate is very convenient to handle and costs approximately $0.016 for each gallon of the diluted spray, when used at the rate of 1 part to 800 parts of water.

TIME AND NUMBER OF SPRAY APPLICATIONS.

Unfortunately no specific dates, which will hold for every season, can be fixed for the applications of the spray. The investigations of the seasons of 1910 and 1911 have shown that the date on which the thrips first become numerous and injurious and the navel-orange blossoms lose their petals varies as much as 30 days in certain seasons, due to the nature of the spring weather, and, further, that it varies in different orchards in the same season. The greatest injury to the fruit is done between the time the petals fall and the fruit is half grown. It has been demonstrated that three applications of the insecticide are necessary during this period to prevent marking of the fruit. The first spring growth has usually hardened by the time

the petals have all fallen, and the thrips then seek the young fruit. The petals do not all fall at once, but come down gradually, and the transfer of thrips is therefore gradual.

The first application should be made as soon as four-fifths or more of the petals have fallen. This checks the insect at a time when the orange is most susceptible of deep injury and when the blossoms have passed the period at which pollination might be interfered with by the spray.

After the first application more larvæ will issue from eggs deposited in the very young fruit, and additional adults will appear from the specimens pupating at the time of the application. The second application must therefore be timed to prevent this renewed attack, which may be expected to reach the danger point in from 10 to 14 days after the first spraying. This second spraying should not be too long delayed, as a comparatively few larvæ may, by their persistent habit of feeding in a circle about the base of the fruit, cause considerable injury. Special effort should be made to drench all the fruit as well as the few remaining tender leaves thoroughly, as it is here only that the insects occur.

The third application may be longer delayed if the first two have been thorough and well timed. It generally takes the insects from two to three or four weeks to become dangerously numerous again, as they reinfest the sprayed trees very much more slowly after the second application.

After the third application the fruit rapidly loses its attractiveness, and the insects then find it necessary, in order to secure food, to spread out over the few remaining tender orange leaves and certain miscellaneous food plants. During the latter part of August and in early September there is usually another abundant growth of shoots upon which the thrips congregate in great numbers. A fourth application in late August or more probably in September should be timed to catch the insects as soon as they become numerous and before any great amount of leaf injury appears.

The importance of protecting this growth is evident to those familiar with the stunted condition of orange trees in certain orchards of Tulare County as the result of continuous feeding of large numbers of thrips during the first five or six years of growth. The writer has in mind an orchard in which trees five years from the nursery are no larger than the average 2-year-old trees in localities more favorably situated with regard to thrips, and which each year have a very large percentage of the leaves so severely injured that they roll up into tight curls.

SPRAY APPLICATIONS TO NURSERY STOCK.

While definite dates can not be given for the application of sprays to nursery stock, it follows in the case of trees budded in the fall, where the original stock is allowed to put forth a good growth in the spring, that it is sometimes advisable to spray during April, but only when thrips have become quite numerous and for the purpose of ridding the trees of them before the scion has grown sufficiently to attract them. Preferably the stock should be largely cut back as soon as the bud is well under way, and this is generally done in Tulare County before May 1. The prunings should be burned in every case to destroy eggs and larvæ which may be present. The growing scions must then be watched carefully, and as soon as thrips appear in numbers spraying should begin. They should be further watched with the same care throughout the remainder of the growing season and sprayed as often as the abundance of thrips makes them liable to severe injury. Nursery stock will usually require from three to five applications a season, depending largely on the amount of growth it produces. Once the scion has completed its first growth and become distasteful to thrips the next most important growth will usually occur late in July or in August.

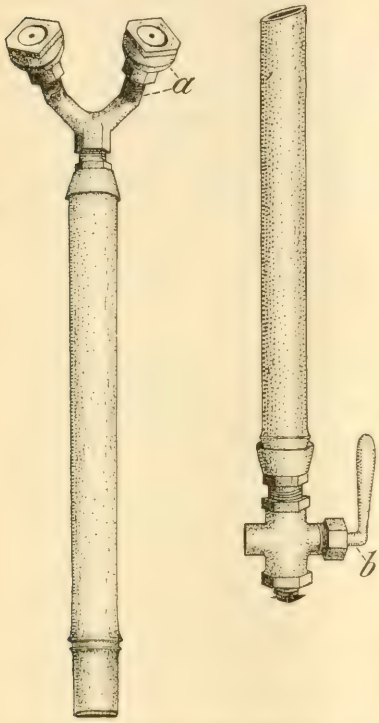

FIG. 5.—Correct spray rod and nozzle connections: *a*, Two nozzles fitted on "Y" branch; *b*, shut-off at base of spray rod. (Original.)

To summarize, the first application should be made when thrips begin to get numerous on the spring growth, usually between April 15 and May 15, after which from two to four further applications will be necessary, according to the conditions of infestation.

SUGGESTIONS ABOUT SPRAYING.

The gasoline-power outfit, by reason of its large nozzle capacity, simplicity, reliability, and comparatively low cost of operation, is the only class of sprayer here recommended for spraying bearing orchards, young orchards in excess of 10 acres, and large nurseries. Hand-power outfits, when of the right type and capable of maintaining a pressure of not less than 125 pounds, are suitable and even preferable

for spraying seed-bed and nursery stock, and they may also be used in young orchards of small acreage.

The spraying outfit should be on hand, set up, and in perfect running condition not later than April 1, and the insecticide materials at hand and conveniently located near the water supply, and as close as possible to the orchard or nursery to be sprayed. It is necessary to order supplies not later than the January or February preceding the spraying operations in order to insure having the material at hand when wanted.

HOW TO SPRAY BEARING ORCHARDS.

It is best to use only two 50-foot leads of hose on a power outfit, with 10-foot rods each fitted with a "Y" (fig. 5) which is angled to handle two nozzles. The latter should be of the large chamber type, with disks bored to one-sixteenth inch, and should throw a double cone of spray which breaks into a fine mist at about 4 feet (fig. 6). The first application should usually be started just before all the petals are down. While the sprayer is being driven between the rows each rodman should begin work at about the middle of his tree on the side away from the sprayer and work around the tree until he meets the starting point; he should then switch to the same point on the next tree without shutting off the nozzles and with as much economy of movement as possible. (See figure 7, which shows easy and correct position for spraying.)

FIG. 6.—Mist spray from twin nozzles. (Original.)

The nozzles should be held about 2 feet from the tree so that the broad portion of the stream plays upon fruit and leaves. The trees should be swept from tip to base, special attention being given to the fruit and the tender growth, where the insects congregate. The pressure, if maintained at 150 pounds or more, will turn the leaves over so that both sides will be sprayed. No

attention need be paid to the inner portions of the tree, as thrips do not occur there.

One should not attempt to spray too many trees with a single outfit, and an application once commenced should be finished within 10 days. It has been found after much experience that only about 25 acres of from 12 to 18 year old trees or 50 acres of from 5 to 7 year old trees can be successfully handled with one gasoline-power sprayer. This is calculated on the basis of ten 200-gallon tanks of spray per day, allowing 8 gallons per tree for trees from 12 to 18 years old or 4 gallons for trees from 5 to 7 years old, allowing 100 trees to the acre. It is a common mistake to use the wash too sparingly and to try to get over the ground too fast. Table I, published also in a former report,[1] was prepared to show approximately the correct amounts to apply to trees of different ages, and from it the quantity of spray material required for the season may be estimated.

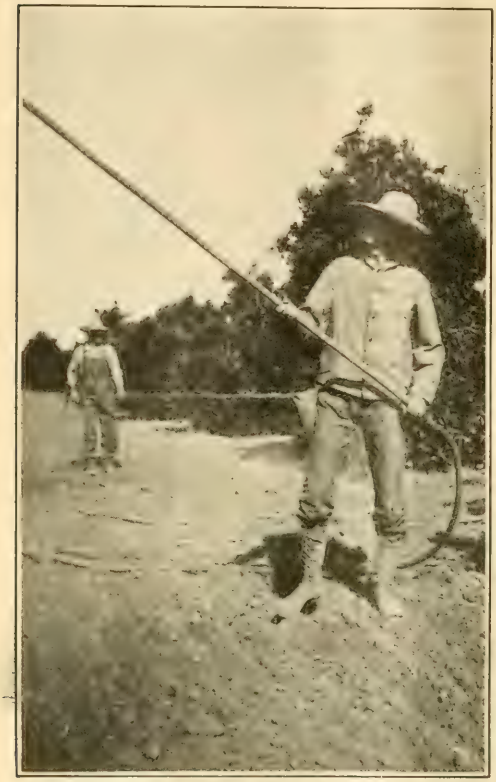

FIG. 7.—Correct position of operator in spraying. (Original.)

TABLE I.—*Quantities of liquid required in spraying for the citrus thrips.*

Age of trees.	One application.	
Years.	Gallons dilute spray per tree.	Gallons per acre of 100 trees.
2 to 3...	2	200
5 to 7...	4	400
8 to 10...	5	500
12 to 18.	8	800

[1] Jones, P. R., and Horton, J. R. The Orange Thrips: A Report of Progress for the Years 1909 and 1910. U. S. Dept. Agr., Bur. Ent., Bul. 99, pt. 1, iv+16 p., 2 fig., 3 pl., Mar. 6, 1911. See p. 15.

The spraying must be very thorough, and to be effective the insects must actually be hit by the spray. It will very much improve the results if the rodmen are shown the insect they are to spray for and just where it will be found in greatest numbers. In this way the object of spraying is made definite. By keeping the thrips reduced to a minimum during the period between the dropping of the petals and the time when the fruit is half grown, most of the fruit scarring and the leaf curl of the early summer growths of foliage can be prevented. An application at the proper time in late August or in September will prevent the severe leaf curling which usually occurs to all late summer growths.

HOW TO SPRAY NURSERIES AND YOUNG TREES.

For large nurseries, where the gas-engine outfit can be advantageously used, it is preferable to the hand outfit. Two 25-foot or even 15-foot leads of hose and 12-foot spray rods are generally most convenient for this work. However, when an outfit has already been fitted with 50-foot hose and 10-foot rods, with the intention of spraying older trees as well as nursery stock, this equipment may be made to serve very well for the latter. In such case the excess hose length should be coiled over a peg or bracket fastened to the spray tank or engine hood, so that the young trees will not be injured by the dragging hose. It is preferable in setting out a nursery to leave driveways wide enough to accommodate a sprayer and team at intervals throughout the length of the bed. Where it is desired to have the nursery rows 4 feet apart, which is the usual practice, it is convenient to have wagon room between the fourth and fifth rows from one side, and again between the 12th and 13th, 20th and 21st, etc. With this arrangement eight rows of trees, four either side of the driveway, may be reached each trip, using 12-foot spray rods; eight more rows may be taken on the return trip, etc.

The large chamber-type or single Bordeaux nozzles may be used to good advantage, but the rapidity of delivery of the spray need not be so great as that necessary for orchard work. It is better to progress more slowly, covering all portions of the little trees, without undue waste of liquid. The trees will need attention only when the growth is tender.

COST OF SPRAYING AS COMPARED WITH RETURNS.[1]

Thrips injury to citrus fruits is confined to the rind and does not appreciably affect the eating quality of the fruit. Except in seasons of unusually gross infestation no great amount of fruit is lost entirely by reason of thrips injury. The argument has been advanced that where the fruit is separated into but two commercial grades, which embrace everything fit to ship, as is now largely the case, thrips injury will have but little effect on the price. The damage thrips do to the trees by interfering with the functions of the leaves throughout the early years of growth, however, is generally overlooked. The following statement takes no account of this indirect injury to the trees, which is difficult to estimate, but merely gives the profit realized from producing a better grade of fruit by spraying.

Cost of spraying one acre of 18-year-old navel orange trees.

Labor:	
2 rodmen at $2.50 each per day, cost per acre	$1.22
Driver and team at $5 per day, cost per acre	1.23
Cost of labor per acre, one application	2.45
Insecticide:	
14 gallons lime-sulphur at 14 cents, cost per acre, one application	1.96
Fuel, oil, and miscellaneous:	
Gasoline, 1½ gallons at 25 cents, per acre, 3 applications	.625
Oil at $1 per gallon, per acre, 3 applications	.025
Repairs and batteries, per acre, 3 applications	.21
Estimated cost of fuel, oil, etc., per acre, 3 applications	.86
Cost of labor per acre, 3 applications	7.35
Cost of insecticide per acre, 3 applications	5.88
Cost of fuel and miscellaneous per acre, 3 applications	.86
Total cost of treating 1 acre of 18-year-old navel orange trees	14.09

Returns from sale of fruit.

Number of packed boxes fruit produced per acre	324
Per cent of fruit raised from second grade to first grade by spraying	18
Boxes raised from second grade to first grade by spraying	58
Difference in price received per box for first-grade over second-grade fruit	$0.51
Amount saved per acre by spraying	$29.58

Profit from sale of fruit.

Amount saved per acre by spraying	$29.58
Cost of spraying per acre	14.09
Clear gain per acre from the treatment	15.49

[1] The figures given upon cost of spraying are based on the Bureau of Entomology's own spraying work in the season of 1911. The number of boxes of fruit given, 324 per acre, was the actual production of the portion of grove under experiment, and as these trees were not at their best and since 18-year-old trees usually produce more than 324 boxes per acre, the saving effected by spraying would tend to be greater in most cases. The difference of $0.51 per box between first and second grade fruit was that which was actually shown by packing-house returns, and practically all the grade reduction was caused by thrips alone.

In the above calculation the cost of spraying an acre of 18-year-old trees is higher than will usually be the case, since, as a rule, the grower is obliged to have a team on hand all the time and may therefore reduce the item of team hire; he may also be able to reduce the cost of labor somewhat in many cases. In seasons of gross infestation, and in certain orchards every season, the returns will be greatly increased over the figures given because of the excessive infestation in such seasons and orchards.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 675 JULY 6, 1915.

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE ROUNDHEADED APPLE-TREE BORER.[1]

By FRED E. BROOKS,

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INTRODUCTION.

Several species of insects occur in the United States that in their larval or grub stage injure apple trees by boring into the bark and wood. The most destructive of these, in the eastern half of the country, is the roundheaded apple-tree borer. The borers of this species hatch from eggs deposited by a rather large beetle in or under the bark of the trees, usually near to the ground, and feed to such an extent on the inner bark and wood that the trees are greatly weakened and often die as a direct result of the injury. Trees of all sizes are attacked, but those from 3 to 10 years old suffer most. As the borers feed they throw out, through small holes which they make in the bark, sawdustlike castings of a reddish color. (Fig. 11.) Heaps of these castings found at the base of apple, pear, or quince trees are

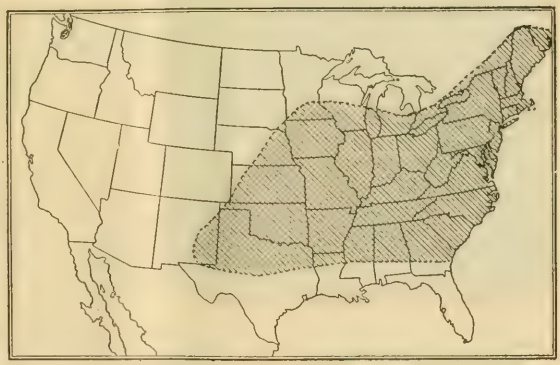

FIG. 1.—Distribution of the roundheaded apple-tree borer (*Saperda candida*). (Original.)

NOTE.—This bulletin describes an insect which in the larval or grub stage is most destructive to apple orchards in the eastern half of the United States. (See fig. 1.) Methods for its control are given.

[1] *Saperda candida* Fab.; order Coleoptera, family Cerambycidæ.

always an evidence that the trees need immediate attention. Frequently an examination of an orchard induced by finding one tree with castings at the base will reveal the fact that many trees are affected and that serious injury has already been done.

In many localities the borers of this species are so abundant that when young apple orchards are neglected practically all the trees will be killed or injured beyond recovery before they are 10 years old. (Fig. 2.)

HISTORY AND DISTRIBUTION.

The roundheaded apple-tree borer is a native of North America, and has been known in this country as an enemy of cultivated fruit trees for nearly a century. Before orchards were planted here it doubtless bred in the wild trees, which it still inhabits.

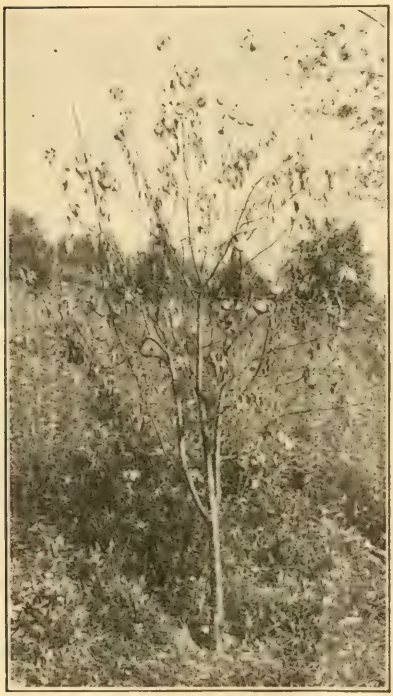

FIG. 2.—Young apple tree dying from injuries caused by roundheaded apple-tree borers. (Original.)

The species was first described by Fabricius in the year 1787. It was redescribed by Thomas Say in 1824, the description containing a note that the insect injured apple trees by boring in the wood. In 1825 it was observed to be attacking fruit trees about Albany, N. Y., and during the same year was reported to have caused a loss estimated at $2,000 in one orchard at Troy, N. Y. Since that time there have been frequent complaints of great injury over a wide scope of country in the eastern half of the United States and southeastern Canada. Instances of the entire destruction of apple and quince orchards by this insect are not uncommon, and the cost and trouble of protecting trees against its ravages amount to an important item in the expense of orchard maintenance throughout the region where the species occurs. Its known range may be bounded by a line extending from near the mouth of the St. Lawrence River westward through Quebec and Ontario to Minnesota, thence through Nebraska, Kansas, New Mexico, Texas, Louisiana, Mississippi, Alabama, and Georgia to the Atlantic coast. (See fig. 1.) Curiously

enough, this line, except in its southwestern extent, bounds also rather definitely the distribution in America of the service tree,[1] which is one of the borer's favorite host trees.

Throughout the range of this insect there are many restricted localities where it does not occur, or, at least, is so rare as to have escaped notice. It is not uncommon to find the borers exceedingly abundant in one orchard while in other orchards, perhaps not more than a mile away, it may never have appeared in sufficient numbers to have attracted attention. This tendency of the species to be present in one locality and absent in an adjoining one is an interesting phase of its distribution. It has been noticed that where soil conditions and other causes favor an abundant growth of wild trees in which the borers breed, near-by cultivated trees will suffer more than where such natural breeding places are not present.

As a rule the parent female beetle in ovipositing does not move far from the tree in which she was developed, providing there are suitable trees near by in which she can place her eggs. (Fig. 3.) This tendency of the female to spend her adult life and provide for her progeny within a restricted area accounts very largely for the irregularity in the local occurrence of the borers. An adult female issuing in an orchard is quite likely to deposit all her eggs within a few rods of her host tree; thus it is that in infested orchards that have not been entirely neglected in respect to this pest the borers are likely to be found infesting groups of half a dozen or more trees standing close together. It is a common observation, especially in newly planted orchards, that the trees standing near to woods in which service, wild crab, or mountain ash trees grow, or those adjacent to old infested orchards, are the ones to be first attacked by the borers. This is so because the woods and neglected orchards are breeding places for the borers, and when the adult insects appear they select the near-by orchard trees for attack. This is an important point to keep in mind in the work of ridding orchards of, and keeping them free from this pest.

FOOD PLANTS.

This borer, so far as is known, confines its attacks to a few species of trees belonging to the family Rosaceæ. Even among the limited number of its host plants the insect shows considerable discrimination, greatly preferring as food some species of trees above others. Of our cultivated fruits, quince, apple, and pear suffer about in the order named. Service (figs. 18, 19), wild crab, mountain ash, thorns of different species, and chokeberry are the wild or native trees which serve as its food. These wild trees are named, also, about in

[1] *Amelanchier canadensis.*

the order for which preference is shown, service, crab, and mountain ash being more often attacked than the others.

The relation of native host trees to the local distribution of the borers is important. Frequently a clump of these trees growing in a neglected field or those growing in the woods will be infested

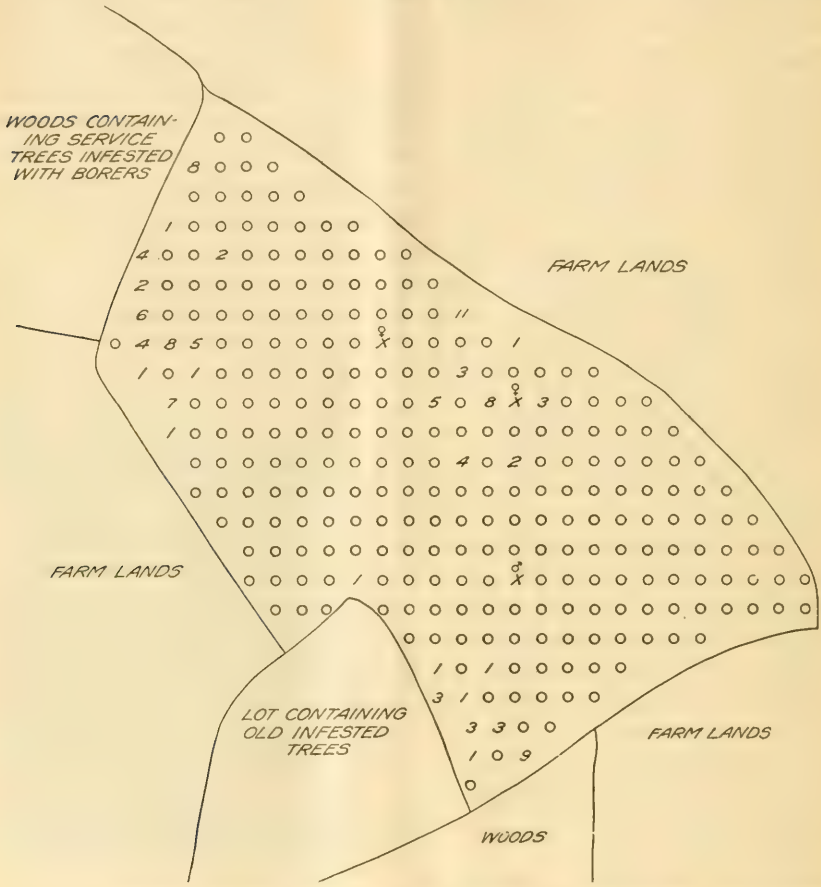

FIG. 3.—Diagram of orchard illustrating the tendency of the adult female roundheaded apple-tree borers to group their eggs about the places where they develop. o, o Represent trees; × represents trees from which male and female beetles issued in 1914; figures represent number and position in the orchard of eggs deposited in 1914. Note how eggs are grouped about the two orchard trees from which females issued, the lot containing old infested apple trees and the woods in which the borers breed in service trees. (Original.)

and will year after year be a source, and possibly the principal source, from which adult insects are produced to fly out and deposit eggs in adjacent orchards.

In exceptional cases peach, cherry, and plum trees are said to be attacked by this species, but this occurs very rarely, the common peach borer being the larval form of an entirely different insect.

LIFE HISTORY.

To pass through the four forms or stages of its life cycle this insect requires in some cases two years and in others three years. In the central part of West Virginia about two-thirds of the individuals reach the adult stage the second season after hatching, while the other third do not become adult until the third season from the egg. It is quite probable that throughout its northern range most or all of the individuals require three years to complete the life cycle, while farther to the south, where the annual period of feeding is longer, all the borers may pass through the same transformation in two years.

THE EGG AND OVIPOSITION.

The adult borers issue from the trees during late spring and early summer, the emergence of the brood occupying a period in any given locality of from 15 to 20 days. Between the southern and northern limits of the species' range the calendar dates of the beginning and ending of the emergence of adults probably vary about two months.

FIG. 4.—Egg punctures of roundheaded apple-tree borer in apple bark. Three punctures are to be seen. Natural size. (Original.)

The beetles occasionally fly by night, but are less nocturnal in their habits than was formerly supposed. Emergence from the trees takes place by day, as does the laying of most, and probably all, of the eggs. The males appear two or three days in advance of the females and usually die first. In a week or 10 days after the females issue egg laying begins and is continued for 40 or 50 days, a single female depositing normally from 15 to 30 eggs. In preparing a place for the egg the female makes use of her jaws to cut a short, curved incision in the bark (fig. 4); then with her strong, extensile ovipositor she forces a side opening from the bottom of the incision (fig. 5), at the end of which a single egg is placed. During the period of oviposition a female may pass several days without depositing eggs and may then lay from 1 to 5 within an hour. Usually at least 2 or 3 eggs are laid at a time, the operations attending the laying of each following close together. The several eggs are as a rule placed in one tree. This explains the fact, which has often been noticed,

that where one borer is found others are quite likely to be in the same tree.

The eggs are inserted through the opening in the bark and are placed from one-fourth to one-third of an inch to one side of the entrance. In young trees they are deposited between the bark and wood (fig. 6), but in old, thick-barked trees they may be placed between the layers of bark.

The yellowish or rust-brown egg (fig. 6) is slightly more than one-eighth of an inch long by one twenty-fifth of an inch wide at the middle, both ends tapering to the rounded points. The shell is tough and plastic, allowing the egg to shape itself more or less to the space which it occupies in the tree. The eggs hatch in from 15 to 20 days. As a rule they are placed in the tree just above the surface of the ground. Where the female can find a crack or opening between the soil and the base of the tree large enough to enter, she may place eggs an inch or so below the surface of the ground (figs. 7, 8). Rarely the eggs are deposited higher in the tree about a crotch or an uneven place on the trunk. In the latitude of West Virginia and Maryland egg laying is in progress from the last of May until the middle of July, the period being somewhat later in the season than the dates given at the higher elevations of the mountain districts.

FIG. 5.—Adult female of the roundheaded apple-tree borer in the act of depositing an egg. Slightly enlarged. (Original.)

THE LARVA.

The larva, or borer (figs. 9, 10), is a whitish, footless grub, with brown head and black jaws. It attains a length when full grown of nearly an inch and a half. On hatching, the young borers attack the inner bark, where they continue to feed until late in the season; whereupon some of them, especially in young trees with thin bark,

gnaw their way into the sapwood. During the first season the young borers feed and grow rapidly, and where several occur in one tree they may completely girdle and kill it before winter. Their burrows at this time are in the form of broad, irregular, usually more or less circular galleries beneath the outer bark, near to the point where the egg was laid. The borers avoid one another in the tree, and the forms of their galleries are often affected thereby, being made narrower and more elongate to avoid contact. This habit increases the liability of their being overlooked by orchardists who practice the digging-out, or "worming," method.

FIG. 6.—Inner surface of bark peeled from young apple tree showing position of eggs of roundheaded apple-tree borer. Natural size. (Original.)

As the borers feed they keep an open space in the burrows about themselves, thrusting their castings into abandoned corners or out through small holes made by them in the bark. These castings form little heaps of reddish, stringy wood fragments around the base of the tree (fig. 11) and afford one of the sure marks by which infested trees may be detected.

FIG. 7.—Female beetle splitting the bark of a young apple tree just below the surface of the ground preparatory to depositing an egg. (Original.)

The borers spend their first winter in the burrows near the ground and resume feeding early the following spring, attacking now the solid wood almost exclusively, and, in young trees, penetrating to the heart. During the summer those that are to attain the adult stage the following year begin to extend their burrows up the trunk a half

inch or more beneath the bark. As previously stated, part of the borers do not become adult until they are 3 years old; these remain feeding in the wood near the ground until the third summer, when they, too, work their way up the trunk in the manner just described. The winter previous to pupation is passed by the borers in the pupal cell or chamber (fig. 12). This chamber is a space at the upper end of the gallery which curves out to the inner bark above and contains in the curved portion next to the bark a small quantity of fine, sawdust-like particles of wood. The chamber is 2 or 3 inches in length, being limited at the lower end by a packing of coarse, string-like wood fiber. In the spring the point at which the chamber extends to the inner bark begins to show from the outside as a slightly depressed, dead spot in the bark. This spot marks the place from which the adult is to issue later, and is especially noticeable on young, smooth-barked trees.

FIG. 8.—Female beetle placing an egg in the tree below the surface of the ground. (Original.)

THE PUPA.

The pupa (fig. 13) is an intermediate form between the larva, or borer, and the beetle which deposits the eggs. In this form the insect is of about the same color as the borer, but the shape is greatly changed, the legs, wings, antennæ, and other appendages which the adult is to possess being now visible. The insect does not feed while in this stage and is incapable of motion except that of wriggling about in the chamber. It occupies a vertical position in the tree with its head up. The change from the borer to the pupa takes place at the time apple trees are in bloom, the pupal stage covering a period of about three weeks.

THE ADULT.

The borer attains the adult stage 10 days or 2 weeks before it leaves the pupal chamber. When ready to issue it gnaws a circular hole through the bark (fig. 14) and escapes.

The beetles average about three-fourths of an inch in length, exclusive of the antennæ. The color is light brown above with

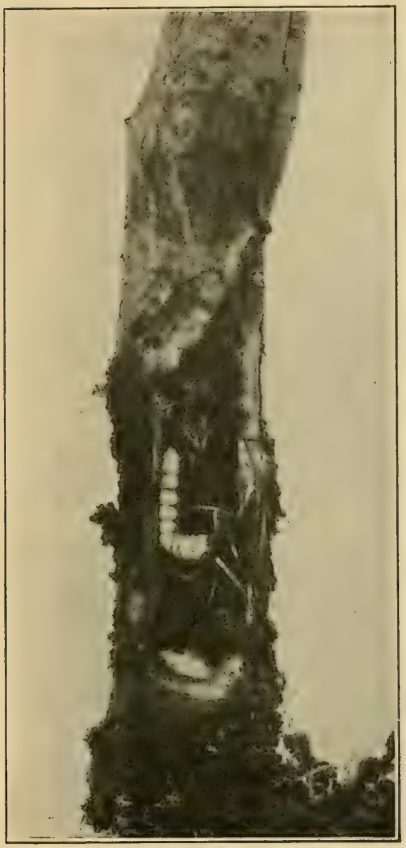

FIG. 9.—Roundheaded apple-tree borer. First summer in tree. Natural size. (Original.)

FIG. 10.—Roundheaded apple-tree borer. Second summer in tree. Natural size. (Original.)

two broad, white bands, joined in front, extending the full length of the back; the underparts and front of the head are white. The female is larger than the male, the body being thicker and heavier. (Fig. 15.)

All the beetles in a given locality issue from the trees within a period of two or three weeks. After they emerge they seek the branches of the trees, where they spend the greater part of their lives

resting among the foliage. The females make short flights in search of trees in which to oviposit. Rarely they fly for a considerable distance, but where suitable trees in which to deposit eggs are abundant they usually pass their lives within a few rods of the trees from which they issue. (Fig. 3.) The males in seeking their mates make longer and more frequent flights. Both sexes are active by day and at twilight in warm weather, and, although they occasionally fly at night,

FIG. 11.—Castings of roundheaded apple-tree borers at base of young apple tree. (Original.)

the hours of darkness are more likely to be spent in quiet among the branches.

The adults do considerable feeding on the bark of twigs and on the midribs and stems of leaves (fig. 16), and they also show a fondness for the moisture that is contained in castings thrown from trees by borers still in their larval stage. This habit is not important from the standpoint of any noticeable injury which such feeding does to the tree, but it causes the death of some of the beetles when they

feed from trees that have been sprayed with arsenical poisons and suggests spraying with arsenicals as a possible means of combating the borers.

When ready to oviposit the female usually crawls down the trunk of the tree to the ground and slits the bark with her mandibles (figs. 4, 7), after which she turns around, inserts her ovipositor into the slit (fig. 5) and deposits an egg, the whole operation occupying about 10 minutes. She may deposit as many as 5 eggs without resting and will then crawl back up the trunk or move away a short distance over the ground and fly to the branches above or to a neighboring tree.

The average life of a beetle is about 40 or 50 days, although individuals occasionally live to be 70 or 75 days of age.

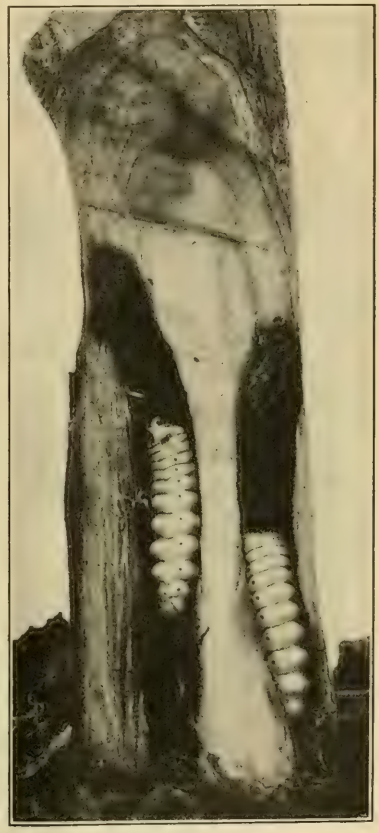

FIG. 12.—Roundheaded apple-tree borers in pupal chambers. Position occupied during winter previous to emergence as adults. (Original.)

NATURAL ENEMIES.

All observers agree that woodpeckers destroy great numbers of the borers by drilling into the trees and removing them from their burrows. The marks made by these birds in searching for borers may be found in the trunks of trees in almost any infested orchard. In some cases from 50 to 75 per cent of the borers are destroyed in this way. Most of the borers devoured are taken from the pupal chamber or while they are making the ascent of the trunk preparatory to pupation. It is rather unfortunate that the birds so often wait until the borers have done the principal part of their injury to the tree before they remove them. Probably both the hairy and downy woodpeckers feed on the borers.

One hymenopterous parasite, *Cenocoelius populator* Say, has been reported from Indiana, but in many localities this species is doing very little in the way of holding the borers in check.

METHODS OF CONTROL.

This insect in its borer stage lives and feeds under the bark where no poisonous or contact sprays or washes can be directed against either its food or its body, and consequently it has always been considered a difficult pest to control. Modern insecticides have not been used so successfully against it as against many other common insect

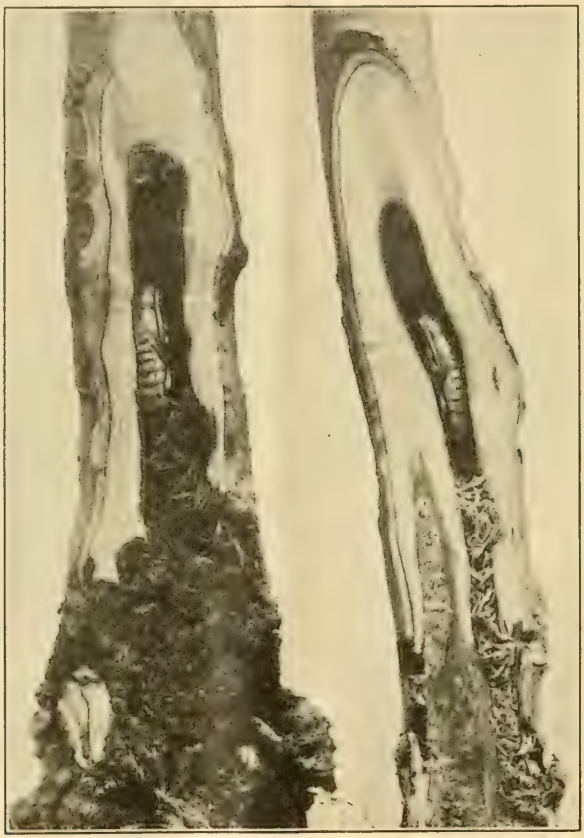

FIG. 13.—Pupæ of roundheaded apple-tree borer. (Original.)

enemies of the orchard. However, there are practicable methods whereby the borers may be destroyed, or oviposition prevented, and injury thus greatly reduced or entirely eliminated, even in orchards that have suffered severely. In the use of these methods timeliness and thoroughness are essential factors, just as they are essential in the processes of combating most insect pests.

WORMING.

Removing the borers from trees by the use of a knife and piece of wire, a practice commonly known as worming, is one of the oldest and, when thoroughly done, one of the most effective ways of dealing with this insect. In worming trees the operator should be equipped with a strong pocketknife, a piece of small wire, a vial of carbon bisulphid, a small quantity of cotton batting, and a garden trowel. (Fig. 17.) These articles may be carried very conveniently from tree to tree in a small basket. The knife should have a long, sharp blade and the wire should be bent to form a small hook at one end and a circle or ring at the other. Into the ring a scrap of white or brightly colored cloth should be tied as a safeguard against losing the wire. The trowel is for use in scraping away from the base of the tree any earth or litter that interferes with a close search for castings of the borers. When castings are found the bark should be cut away sufficiently to allow the borer to be traced by its burrows and killed. If the cutting is done with care, and the borer secured, the wound will usually heal without noticeable injury to the tree. The natural healing tendency of the tree may be assisted by covering the wound with lead paint.

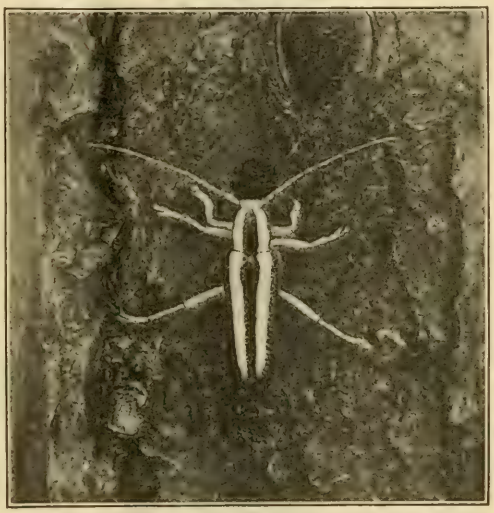

FIG. 14.—Adult roundheaded apple-tree borer just emerged from exit hole in bark. Natural size. (Original.)

During the first few months of its life the borer is easily found and destroyed, but after it has been feeding a year or more the difficulty of locating it is increased, since at that time its burrows extend more deeply into the tree. However, with a little practice one becomes rather adept at securing the borer regardless of its age or the position it may occupy in the wood.

As the borers engage in burrowing in the tree they keep a clear space behind them, and up to the time the pupal cell is being constructed there is usually nothing to prevent inserting the wire into the exposed end of the burrow and hooking them out. While the

pupal cell is being formed, the burrow below, which up to that time has been kept open, is packed for several inches with wood fiber so that the wire can no longer be used successfully. In all cases where curves or other obstructions in the burrows interfere with hooking the borer out, a little cotton batting dipped in carbon bisulphid should be inserted into the hole and the opening plugged with moist earth. The gas coming from the carbon bisulphid will penetrate all parts of the burrow and will kill the borer. It should be borne in mind that the gas is highly inflammable and that fire should be kept away.

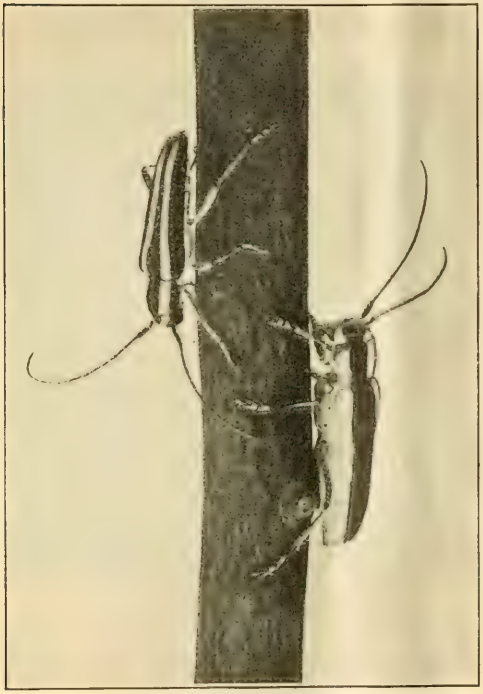

FIG. 15.—Adult male and female roundheaded apple-tree borer. Male on left, female on right. Slightly enlarged. (Original.)

In extensive orchards where worming is done on a large scale by promiscuous labor some of the helpers are likely to become careless and overlook or neglect to destroy an occasional borer. Every female so overlooked stands a good chance of maturing within a year or two, when it will deposit eggs in a half dozen or more near-by trees, causing thereby a continued and an increased infestation in that particular part of the orchard.

The importance of the following points should be kept in mind by all persons who practice this method of borer control:

1. Borers should be removed from the trees as soon as possible after hatching.

2. Every borer in the orchard should be found and destroyed.

3. Borers should not be allowed to breed in cultivated or wild host trees growing within at least 200 or 300 feet of the orchard.

It is the practice with many orchardists to put off the fall worming of trees until after winter apples are gathered. Observations have shown that this practice permits the borers, which feed rapidly while young, to remain in the trees too long for safety. Even in so short a time small trees may be girdled and killed and larger trees seriously injured. In the latitude of West Virginia and Maryland the

work should be done not later than the 1st of September; farther south it may be done several weeks or a month earlier, and north of the States mentioned the time will be correspondingly later. A second examination should be given the trees the following spring to secure borers from belated eggs or those that may have been overlooked at the fall worming.

The fact that the adult female does not habitually wander far in depositing her eggs (see fig. 3) is greatly to the advantage of the orchardist who depends on worming to save his trees. When once his

FIG. 16.—Twig and leaf of apple gnawed by adult roundheaded apple-tree borer. (Original.)

orchard and all surrounding host trees are cleared of the borers he is likely thereafter to be troubled very little by new infestations so long as adults are kept from developing within the area. He should continue his examinations of the trees every year, however, to detect in time any fresh outbreaks arising from eggs deposited by adults that may occasionally fly into the orchard from a distance. Where this method is used all worthless trees in which the borers can breed, growing within a few hundred feet of the orchard, should

be removed. This would include service (figs. 18, 19), mountain ash, wild crab, and thorn trees in woods, as well as the cultivated fruit trees.

PAINTS AND WASHES.

Paints and washes of various kinds have frequently been recommended for use on the trunks of trees, both to prevent the beetles from depositing eggs and to kill the borers within the trees. Experience has shown that it is easier by such means to prevent the eggs from being laid than to kill the borers. Some orchardists report success by applying pure kerosene to the bark of affected trees at the places where castings show borers to be at work. The kerosene is supposed to penetrate the burrow to the insect and kill it. Others have found that this treatment does not destroy enough of the borers to make the remedy worth while, and that in addition the kerosene may kill the bark at the point of application. The danger of injury to trees by the use of kerosene or other mineral oil practically prohibits the use of these substances. Milder solutions, applied in the same way, while not so likely to injure the trees, are even less fatal to the borers.

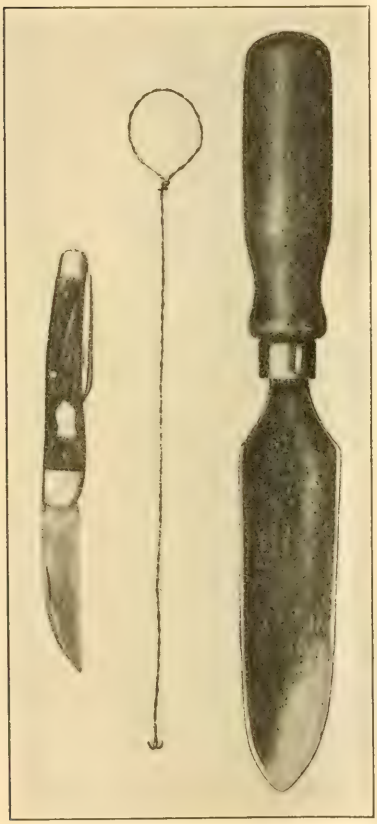

FIG. 17.—Tools for use in removing roundheaded apple-tree borers from burrows. (Original.)

On the other hand, a heavy application, made just before the beginning of the egg-laying season, of some thick paint that will not injure the trees and that will maintain an unbroken coat on the bark for two or three months is very effective in preventing the female from placing her eggs in the bark. The beetle in slitting the bark with her jaws, preparatory to inserting the egg, will very rarely, if ever, make an opening through such a thick coat of paint.

Before applying paint for this purpose the earth around the base of the tree should be removed with a garden trowel or hoe to a depth of 3 or 4 inches. Bark scales and adhering earth should then be scraped from the space to be covered, and the paint applied with a

brush in the form of a band around the tree extending about a foot up the trunk and 2 or 3 inches below the level of the ground. After the paint is dry the earth removed in the beginning should be replaced. The painting may be done more thoroughly and economically by two persons working together on opposite sides of the tree.

The deterrent effect of the paint seems to arise from the mechanical barrier it presents rather than from malodorous or distasteful proper-

FIG. 18.—Clump of service bushes showing exit holes of roundheaded apple-tree borers. (Original.)

ties. The paint should cover the treated portion of the tree in a thick, solid coat, with no cracks or unpainted spaces left, as the beetles will seek out such openings in which to oviposit. Any non-injurious paint that will form a coat of the nature described will answer the purpose. A paint of pure white lead and raw linseed oil, mixed somewhat thicker than for ordinary use, will afford a fair

measure of protection to the tree, providing a heavy coat is applied in a thorough manner just previous to the beginning of the egg-laying season of the borers. The natural growth of the tree will in time cause the paint to crack, but the coat formed by one painting will remain intact and protect the tree during one egg-laying season if applied at the proper time. Better results are likely to be obtained from this treatment on young, smooth-barked trees than on old trees on which the rough bark makes a thorough job of painting more difficult. In the experience of the Bureau of Entomology, apple trees are not injured by the white-lead paint when used as directed. Others have reported injury from supposedly pure white-lead paints, but it is possible that these contained foreign and injurious substances. Those planning to use the raw linseed oil and white-lead paint should insist on receiving this article. There are several so-called tree paints and pruning paints on the market that are valuable for this purpose and appear to be safe for the trees. Annual applications of any of these paints will be necessary.

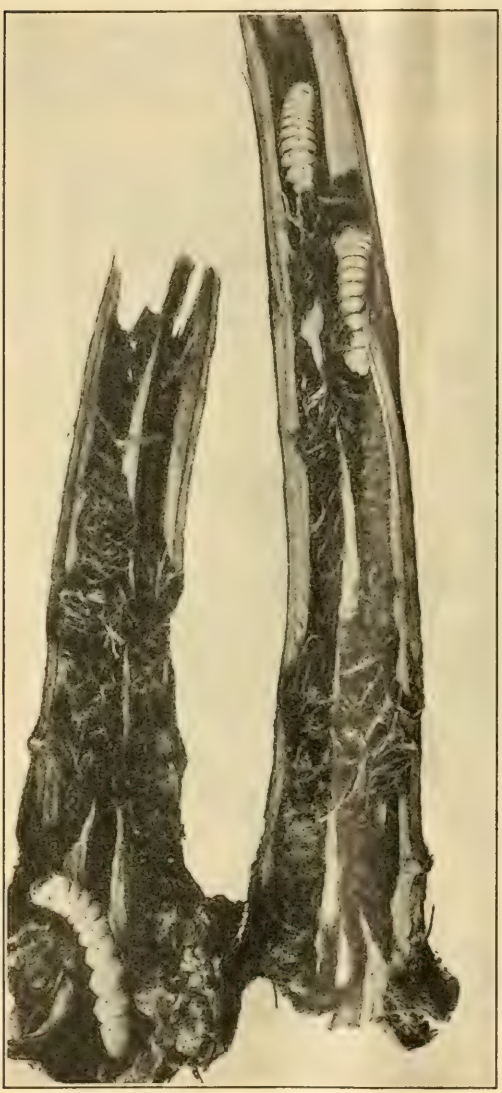

FIG. 19.—Roundheaded apple-tree borers working in young service tree. (Original.)

Gas tar has been used with some success against peach-tree borers, but should be used with caution on apple trees, as there is serious danger of injury to the bark and wood. Axle grease and paints con-

taining considerable quantities of benzine or turpentine can not be used on apple trees with safety. Some persons have had good success from the use of fish-oil soaps and carbolic-acid washes, but in tests made by the Bureau of Entomology these have not proved to be of any benefit.

MECHANICAL PROTECTORS.

Various mechanical protectors or coverings, to be placed around the lower portion of the trunk for the purpose of excluding the female beetle from the bark, have been devised. Wrappers made of newspapers are quite effective for this purpose. These wrappers, or any protectors of like nature, should be placed around the base of the trunks early in May, the season varying with the locality, and should cover the trunk from a foot or so above the ground to a short distance beneath the surface. The earth at the bottom should be mounded around the protector so as to leave no exposed portion of bark at that point. Building paper, cloth, cotton batting, fine-meshed wire screen, moss, and other materials may be used in the same way with success. Tarred paper has been recommended, but tests have shown that trees wrapped with it are likely to be injured thereby.

Such devices as those just described should be tied at the top close to the body of the tree, preferably with a piece of twine, to prevent the beetles from crawling down to oviposit between the trunk and covering. These protectors have the disadvantage of furnishing breeding and harboring places for the woolly aphis, an insect destructive to apple trees, and for that reason they should be removed from the trees as soon as possible after the egg-laying season of the borer is past. It is probably safe to remove them in any locality by the 1st of September. Eggs will be deposited occasionally around the upper margins of the protectors, but the resultant borers are easily located and destroyed. It is doubtful if trees can be protected as economically with devices of this kind as with paint, and since paint of the proper kind is of almost or quite as much value in preventing attack, it may often be used in preference to the other form of covering.

SPRAYING WITH ARSENICALS TO KILL ADULTS.

As is stated on page 10, the borer in its adult stage feeds more or less on the exposed surface of leaves and twigs (fig. 16) and on the moisture contained in fresh castings thrown out by borers still working in the trees. The quantity of food taken in this way is sufficient to enable the beetles to be killed by spraying with arsenate

of lead trees on which they are feeding. It is doubtful if it would pay ordinarily to spray orchards for the purpose of killing this insect alone, but in exceptional cases, where orchards are badly infested and are not surrounded by prolific breeding places, there is little doubt that the treatment would be profitable. Fortunately the beetles are active at the season of the year when arsenical sprays for the codling moth and other orchard pests are usually applied. These sprays, used primarily to destroy other enemies of the orchard, without doubt kill incidentally many adult roundheaded apple-tree borers.

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FARMERS' BULLETIN

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

HOUSE FLIES.

By L. O. HOWARD, *Chief of the Bureau of Entomology*, and R. H. HUTCHISON, *Scientific Assistant*.

CONTENTS.

INTRODUCTION.

There are several species of flies which are commonly found in houses, although but one of these should properly be called the house fly. This fly, *Musca domestica* L. (fig. 1), which is found in

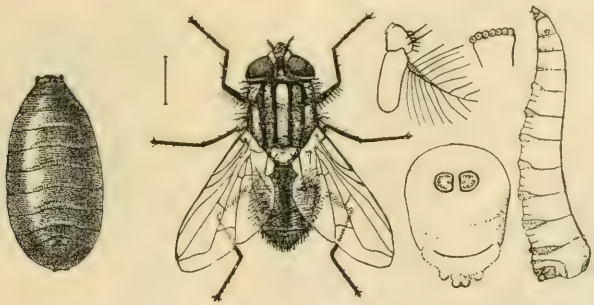

FIG. 1.—The common house fly (*Musca domestica*): Puparium at left; adult next; larva and enlarged parts at right. All enlarged. (Author's illustration.)

nearly all parts of the world, is a medium-sized grayish fly, with its mouth parts spread out at the tip for sucking up liquid substances. On account of the conformation of its mouth parts, the house fly can not bite, yet no impression is stronger in the minds of most people than that this insect does occasionally bite. This impression is due

NOTE.—This bulletin supersedes Farmers' Bulletin No. 459. It will be of interest wherever breeding places for flies are found.

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to the frequent occurrence in houses of another fly (*Stomoxys calcitrans* L.) (fig. 2), which is called the stable fly, and which, while closely resembling the house fly (so closely, in fact, as to deceive anyone but an entomologist), differs from it in the important particular

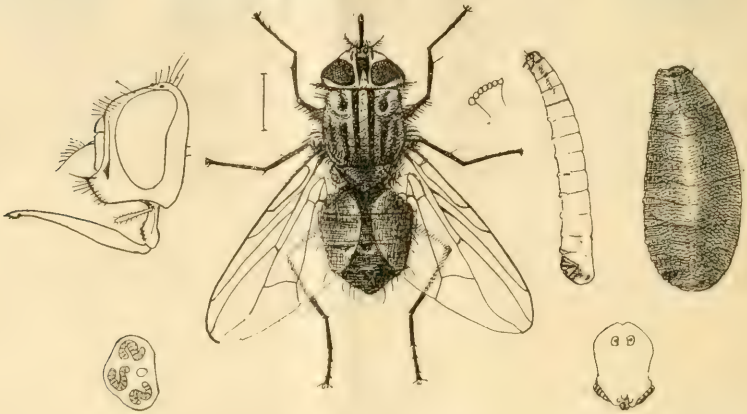

FIG. 2.—The stable fly or biting house fly (*Stomoxys calcitrans*): Adult, larva, puparium, and details. All enlarged. (Author's illustration.)

that its mouth parts are formed for piercing the skin. It is perhaps second in point of abundance to the house fly in most portions of the Northeastern States. It breeds in horse manure, cow manure, and in warm, decaying vegetation, like old straw and grass heaps.

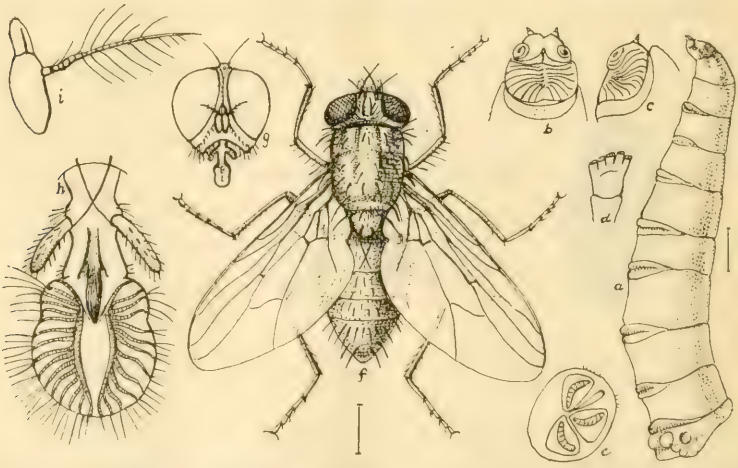

FIG. 3.—A stable fly (*Muscina stabulans*): Adult, larva, and details. All enlarged. (Author's illustration.)

A third species, commonly called the cluster fly (*Pollenia rudis* Fab.), is a very frequent visitant of houses, particularly in the spring and fall. This fly is somewhat larger than the house fly, with a smooth, dark-colored abdomen and a sprinkling of yellowish hairs.

It is not so active as the house fly and, particularly in the fall, is very sluggish. At such times it may be picked up readily, and is very subject to the attacks of a fungous disease which causes it to die upon the window panes, surrounded by a whitish efflorescence. Occasionally this fly occurs in houses in such numbers as to cause great annoyance, but such occurrences are comparatively rare. It is said in its earlier stages to be parasitic on certain angleworms.

FIG. 4.—One of the blue-bottle flies (*Phormia terraenovae*): Adult, enlarged. (Author's illustration.)

A fourth species is another stable fly, known as *Muscina stabulans* Fall. (fig. 3), a form which almost exactly resembles the house fly in general appearance, and which does not bite, as does the biting stable fly. It breeds in decaying vegetable matter and in excrement.

Several species of metallic greenish or bluish flies are also occasionally found in houses, the most abundant of which is the so-called bluebottle fly (*Calliphora erythrocephala* Meig.). This insect is also called the blow fly, or meat fly, and breeds in decaying animal material. A smaller species, which may be called the small bluebottle fly, is *Phormia terraenovae* Desv. (fig. 4), and a third, which is green or blue in color and a trifle smaller than the large bluebottle fly, is *Lucilia caesar* L. (fig. 5).

FIG. 5.—The green-bottle fly (*Lucilia caesar*): Adult, enlarged. (Author's illustration.)

There is still another species, smaller than any of those so far mentioned, which is known to entomologists as (*Homalomyia*) *Fannia canicularis* L., sometimes called the small house fly. A related species, *F. brevis* Rond., is shown in figure 6. *F. canicularis* is distinguished from the ordinary house fly by its paler and more pointed body and conical shape. The male, which is much commoner than the female, has large pale patches at the base of the abdomen, which are translucent when the fly is seen on the window pane. It is this species that is largely responsible for the prevalent idea that flies grow after gaining wings. Most people think that these little fannias are the young of the larger flies, which,

of course, is distinctly not the case. They breed in decaying vegetable material, in excreta of animals, and in dead insects.

Still another fly—and this one is still smaller—is a jet-black species known as the window fly (*Scenopinus fenestralis* L.), which

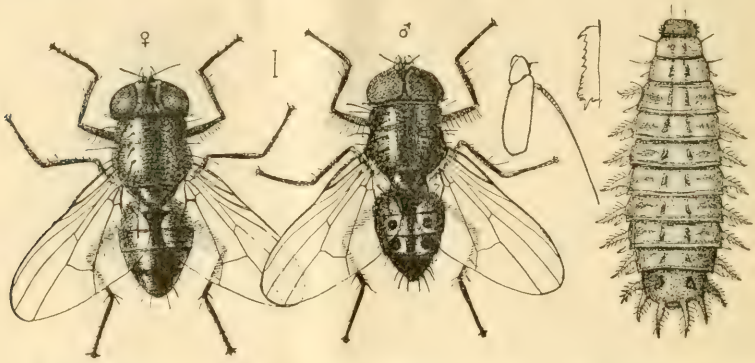

FIG. 6.—The little house fly (*Homalomyia brevis*): Female at left; male next, with enlarged antenna; larva at right. All enlarged. (Author's illustration.)

in fact has become more abundant of later years. Its larva is a white, very slender, almost threadlike creature and is found in cracks of the floor in buildings, where it feeds on other small insects.

In the autumn, when fruit appears on the sideboard, many specimens of a small fruit fly (*Drosophila ampelophila* Loew) (fig. 7) make their appearance, attracted by the odor of overripe fruit.

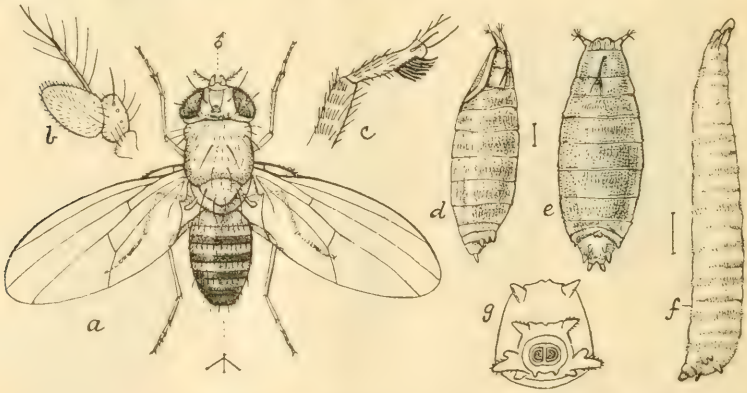

FIG. 7.—The fruit fly (*Drosophila ampelophila*): *a*, Adult; *b*, antenna of same; *c*, base of tibia and first tarsal joint of same; *d*, puparium, side view; *e*, puparium from above; *f*, full-grown larva; *g*, anal spiracles of same. All enlarged. (Author's illustration.)

A small slender fly is not infrequently seen in houses, especially upon windowpanes. This is *Sepsis violacea* Meig., shown enlarged in figure 8.

All of these species, however, are greatly dwarfed in numbers by the common house fly. In 1900 the senior author made collections

of the flies in dining rooms in different parts of the country, and out of a total of 23,087 flies 22,808 were *Musca domestica*—that is, 98.8 per cent of the whole number captured. The remainder, consisting of 1.2 per cent of the whole, comprised various species, including those mentioned above.

LIFE HISTORY OF THE TRUE HOUSE FLY.

Musca domestica commonly lays its eggs (figs. 9, 10) upon horse manure. This substance seems to be its favorite larval food. It will also breed in human excrement, and from this habit it becomes very

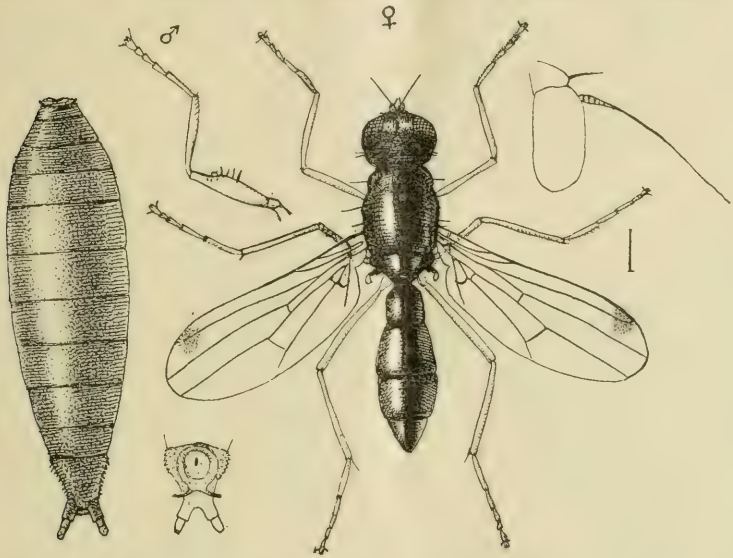

FIG. 8.—The dung fly (*Scepsis violacea*): Adult, puparium, and details. All enlarged. (Author's illustration.)

dangerous to the health of human beings, carrying as it does the germs of intestinal diseases, such as typhoid fever and cholera, from the excreta to food supplies. It has also been found to breed freely in hog manure and to some extent in cow and chicken manure. Indeed, it will lay its eggs on a great variety of decaying vegetable and animal material, but of the flies that infest dwelling houses, both in cities and on farms, a vast proportion come from horse manure.

It often happens, however, that this fly is very abundant in localities where there is little or no horse manure, and in such cases it will be found breeding in other manure or in slops or fermenting vegetable material, such as spent hops, bran, ensilage, or rotting potatoes. Accumulations of organic material on the dumping grounds of towns and cities often produce flies in great numbers.

The number of eggs laid by an individual fly at one time is undoubtedly large, probably averaging about 120, and as a single female will lay at least two and possibly four such batches, the enormous numbers in which the insects occur is thus plainly accounted for, especially when the abundance and universal occurrence of appropriate larval food is considered. The eggs are deposited below the surface in the cracks and interstices of the manure, several females usually depositing in one spot, so that the eggs are commonly found in large clusters in selected places near the top of the pile,

FIG. 9.—Eggs of the house fly. About natural size. (From Newstead.)

where a high degree of heat is maintained by the fermentation below. The eggs usually hatch in less than 24 hours. Under the most favorable conditions of temperature and moisture the egg state may last hardly more than eight hours. The maggots which issue from the eggs are very small and transparent. They grow rapidly and in the course of their development molt twice. There are thus three distinct larval stages, the duration of which is about as follows: (1) From hatching of the larva to first molt, one day; (2) first to second molt, one day; (3) second molt to pupation, two to three days, thus making the total length of the larval stage four to five days. This period may be greatly prolonged by low temperature or by dryness or scarcity of the larval food. As the larvæ (fig. 11)

attain full size they gradually assume a creamy white color. Just before pupation they become very restless and migrate from their feeding ground in search of a favorable place in which to pass the pupal stage. They will often congregate at the edges of manure piles near the ground or burrow into the soil beneath, or they may crawl considerable distances away from the pile to pupate in the ground or in loose material under the edges of stones, boards, etc.

The pupæ (fig. 12), or "sleepers," are more or less barrel shaped and dark brown in color. In midsummer this stage lasts from three to ten days, four to five days being the usual duration. The pupal stage is easily affected by temperature changes and may be prolonged

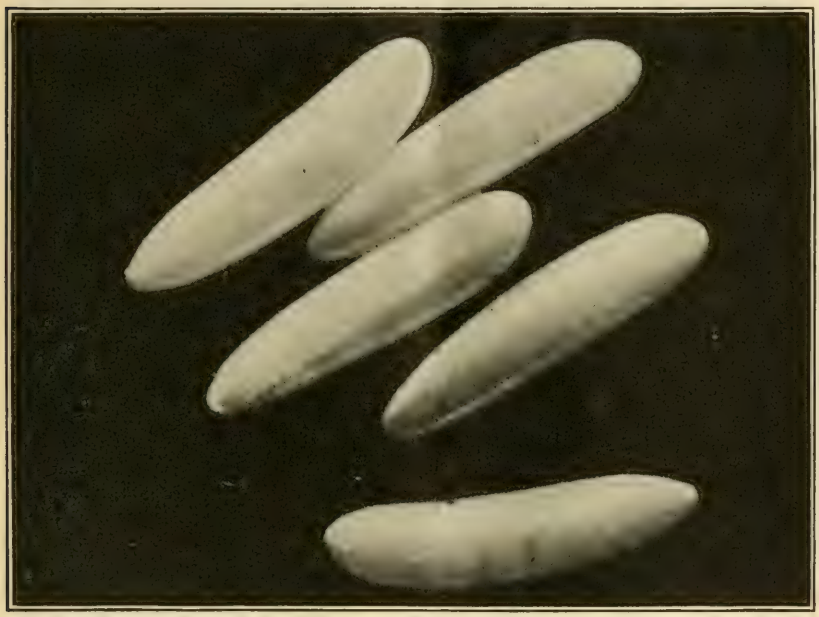

FIG. 10.—Eggs of the house fly. Highly magnified. (From Newstead.)

during hibernation for as long as four or five months. Numerous rearing experiments in various parts of the country have shown that the shortest time between the deposition of eggs and the emergence of the adult fly is eight days, and 10 and 12 day records were very common.

The adult fly, upon emerging from the puparium, works its way upward through the soil or manure and upon reaching the air it crawls about while its wings expand and the body hardens and assumes its normal coloration. In a very few days the female is ready to deposit eggs. In recent experiments at Dallas, Tex., at New Orleans, La., and at Arlington, Va., it has been found that the

time between the emergence of the adults and the first deposition of eggs is considerably shorter than was previously thought to be the case. Only three or four days are necessary in midsummer for the female to reach sexual maturity. As in the case of other periods of its life history, so the preoviposition period is considerably prolonged by the lower temperatures of spring and autumn. In midsummer, with a developmental period of from eight to ten days from egg to adult, and a preoviposition period of from three to four days, there would be a new generation started every 11 to 14 days. There is thus abundance of time in the climate of Washington for the development of 10 to 12 generations every summer.

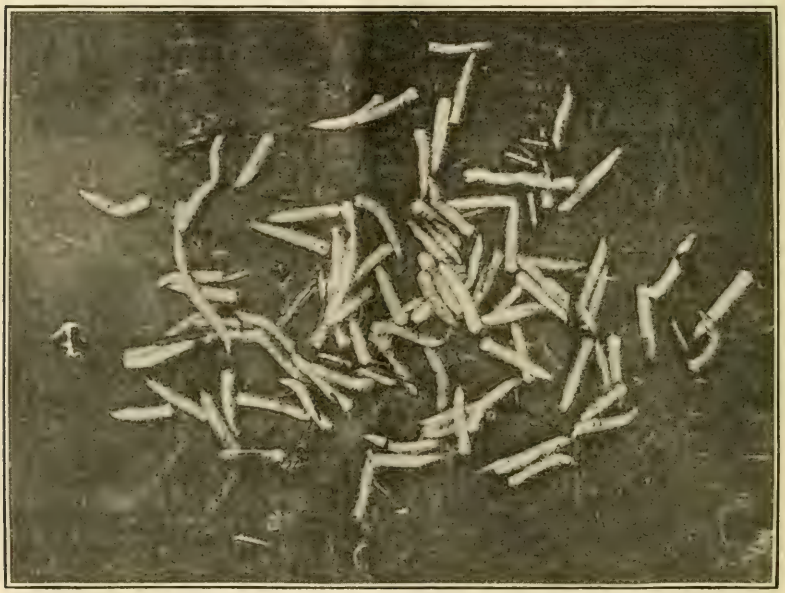

FIG. 11.—Larvæ, or maggots, of the house fly. About natural size. (From Newstead.)

The hibernation of the house fly is a subject to which considerable attention has recently been given, and many new points of practical importance have come to light. The prevailing idea that the house fly passes the winter as an adult, hiding in the cracks and crevices of buildings and in straw stacks, etc., has never been proved experimentally. Messrs. Bishopp, Dove, and Parman made attempts to keep adults in large cages through the winter of 1913–14 at Dallas, Tex. In one experiment in which the cage was kept in a building which was heated during cold periods some flies remained alive for 53 days. In some experiments carried out by the junior author at New Orleans during the same winter all the flies died within a period of 30 days, most of them as a result of the attack of a parasitic

fungus. Careful experiments conducted at the experiment farm at Arlington, Va., during the winter of 1914–15 showed that flies kept in unheated buildings were killed during the first really cold nights of the winter. Those kept in one of the greenhouses behaved just as they would during the summer at similar temperatures. At temperatures of 65° to 75° F. very few lived longer than 35 to 40 days. The best conditions were found in one of the large stables which was slightly heated, the temperature ranging from 32° to 50° F. Some

FIG. 12.—Pupæ of the house fly. About natural size. (From Newstead.)

flies were kept alive here for a period of 70 days, a long period, but not sufficient to carry them through the winter.

Regular collections of flies were made at the Arlington farm during the winter of 1914–15. No living adult house flies were found after the middle of January until April 30, while Pollenia, which does hibernate in the adult state, could be found in buildings almost any time during the winter, and on warm days they were found outside.

On the other hand, there are on record some experiments and observations which indicate that the usual manner in which the house fly passes the winter is in the pupal stage. Bishopp, Dove, and Parman succeeded in two instances in keeping the species through the winter in the larval and pupal stages. Three barrels of heavily in-

fested manure were covered with a large screen cage on November 26, 1913. No adults emerged after December 27 until April 16, 1914, and others on May 26, at which time observations were discontinued. This showed that the house fly lived in the larval and pupal stages for periods of from five to six months. In another case they were kept alive in the immature stages from December 16, 1913, to April 4, 1914. This was at Dallas, Tex.

CARRIAGE OF DISEASE.

The body of the house fly is thickly covered with hairs and bristles of varying lengths, and this is especially true of the legs. Thus, when it crawls over infected material it readily becomes loaded with germs, and subsequent visits to human foods result in their contamination. Even more dangerous than the transference of germs on the legs and body of the fly is the fact that bacteria are found in greater numbers and live longer in the alimentary canal. These germs are voided, not only in the excrement of the fly, but also in small droplets of regurgitated matter which have been called "vomit spots." When we realize that flies frequent and feed upon the most filthy substances (it may be the excreta of typhoid or dysentery patients or the discharges of one suffering from tuberculosis), and that they may subsequently contaminate human foods with their feet or their excreta or vomit spots, the necessity and importance of house-fly control is clear.

In army camps, in mining camps, and in great public works, bringing together large numbers of men for a longer or shorter time, there is seldom the proper care of excreta, and the carriage of typhoid germs from the latrines and privies to food by flies is common and often results in epidemics of typhoid fever.

And such carriage of typhoid is by no means confined to great temporary camps. In farmhouses in small communities, and even in badly cared for portions of large cities, typhoid germs are carried from excrement to food by flies, and the proper supervision and treatment of the breeding places of the house fly become most important elements in the prevention of typhoid.

In the same way other intestinal germ diseases are carried by flies. Asiatic cholera, dysentery, and infantile diarrhea are all so carried. Nor are the disease-bearing possibilities of the house fly limited to intestinal germ diseases. There is strong circumstantial evidence that tuberculosis, anthrax, yaws, ophthalmia, smallpox, tropical sore, and parasitic worms may be and are so carried. Actual laboratory proof exists in the case of a number of these diseases, and where lacking is replaced by circumstantial evidence amounting almost to certainty.

NATURAL ENEMIES.

The house fly has a number of natural enemies. The common house centipede (fig. 13) destroys it in considerable numbers; there is a small reddish mite which frequently covers its body and gradually destroys it; it is subject to the attacks of hymenopterous parasites in its larval and pupal condition; and it is destroyed by predatory beetles at the same time.

The most effective enemy of the house fly, however, is a fungous disease known as *Empusa muscae*, which carries off flies in large numbers, particularly toward the close of the season. The epidemic ceases in December, and, although many thousands are killed by it, the remarkable rapidity of development in the early summer months soon more than replaces the numbers thus destroyed.

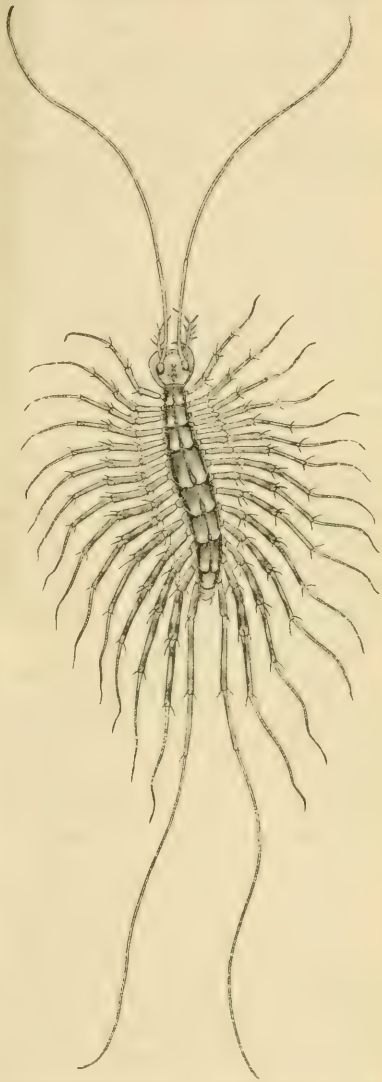

FIG. 13.—The house centipede (*Scutigera forceps*): Adult, natural size. (After Marlatt.)

PREVENTIVE AND CONTROL MEASURES.

THE USE OF SCREENS.

A careful screening of windows and doors during the summer months, with the supplementary use of sticky fly papers, is a preventive measure against house flies known to everyone. As regards screening it is only necessary here to emphasize the importance of keeping food supplies screened or otherwise covered so that flies can gain no access to them. This applies not only to homes, but also to stores, restaurants, milk shops, and the like. Screening will, of course, have no effect in decreasing the number of flies, but at least it has the virtue of lessening the danger of contamination of food.

FLY PAPERS, POISONS, AND TRAPS.

In the effort to destroy flies that have gained access to houses the use of sticky fly papers is very common. Another way is to expose in shallow dishes a mixture of formalin and milk or water, sweetened with a little sugar (1 teaspoonful of commercial formalin to 1 teacupful of water or milk). This is most effective when no other liquids are accessible to the flies. Formalin diluted in this manner is not poisonous to man and will not injure fabrics. In this respect it is much safer than the fly poisons containing arsenic.

Burning of fresh pyrethrum powder is also effective in killing flies in rooms.

Flytraps may be used to advantage in decreasing the number of flies. There are many kinds on the market, and as a rule the larger ones are the more effective. These should be placed on the outside of houses, stores, stables, etc. Bananas, sugar and vinegar, milk, and beer will be found to be attractive baits under most circumstances. The use of flytraps has been enthusiastically advocated by Prof. C. F. Hodge, not only because of the immediate results, but because of the chances that the flies may be caught before they lay their first batch of eggs, and thus the possible number of future generations will be greatly reduced. From what was said above in regard to the preoviposition period it will be apparent that flytraps will be more effective in this respect during the spring and autumn months than during midsummer.

The use of fly papers, poisons, and traps are at best only temporary measures. The most logical method of abating the nuisance is the elimination or treatment of all breeding places. It would appear from what we know of the life history and habits of the common house fly that it is perfectly feasible for cities and towns to reduce the numbers of these annoying and dangerous insects so greatly as to render them of comparatively slight account.

CONSTRUCTION AND CARE OF STABLES.

In formulating rules for the construction and care of stables and the disposal of manure the following points must be taken into consideration. In the first place, the ground of soil-floor stables may offer a suitable place for the development of fly larvæ. The larvæ will migrate from the manure to the soil and continue their growth in the moist ground. This takes place to some extent even when the manure is removed from the stables every day. Even wooden floors are not entirely satisfactory unless they are perfectly water-tight, since larvæ will crawl through the cracks and continue their development in the moist ground below. Water-tight floors of concrete or masonry are therefore desirable.

Flies have been found to breed in surprising numbers in small accumulations of material in the corners of feed troughs and mangers, and it is important that such places be kept clean.

FLY-TIGHT MANURE PITS OR BINS.

The Bureau of Entomology has for some years advised that manure from horse stables be kept in fly-tight pits or bins. Such pits can be built in or attached to the stable so that manure can be easily thrown in at the time of cleaning and so constructed that the manure can be readily removed. The essential point is that flies be prevented from reaching the manure, and for this reason the pit or bin must be tightly constructed and the lid kept closed except when the manure is being thrown in or removed. There is no doubt as to the effectiveness of this method when the necessary precautions are taken, especially if the manure is removed at frequent intervals.

FREQUENCY WITH WHICH MANURE SHOULD BE REMOVED.

Another point must be considered in deciding the question as to how often the manure should be removed. In this connection it should be borne in mind that when the larvæ have finished feeding, they will often leave the manure and pupate in the ground below or crawl some distance away to pupate in débris under boards or stones and the like. Hence the manure should be removed before the larvæ reach the migratory stage; that is to say, removal is necessary every three days, and certainly not less frequently than twice per week during the summer months. A series of orders issued in 1906 by the Health Department of the District of Columbia, on the authority of the Commissioners of the District, covers most of these points, and these orders, which may well serve as a model to other communities desiring to undertake similar measures, may be briefly condensed as follows:

HEALTH OFFICE REGULATIONS FOR CONTROL OF HOUSE FLIES IN CITIES.

All stalls in which animals are kept shall have the surface of the ground covered with a water-tight floor. Every person occupying a building where domestic animals are kept shall maintain in connection therewith a bin or pit for the reception of manure and, pending the removal from the premises of the manure from the animal or animals, shall place such manure in said bin or pit. This bin shall be so constructed as to exclude rain water and shall in all other respects be water-tight, except as it may be connected with the public sewer. It shall be provided with a suitable cover and constructed so as to prevent the ingress and egress of flies. No person owning a stable shall keep any manure or permit any manure to be kept in or upon any portion of the premises other than the bin

or pit described, nor shall he allow any such bin or pit to be overfilled or needlessly uncovered. Horse manure may be kept tightly rammed into well-covered barrels for the purpose of removal in such barrels. Every person keeping manure in the more densely populated parts of the District shall cause all such manure to be removed from the premises at least twice every week between June 1 and October 31, and at least once every week between November 1 and May 31 of the following year. No person shall remove or transport any manure over any public highway in any of the more densely populated parts of the District except in a tight vehicle, which, if not inclosed, must be effectually covered with canvas, so as to prevent the manure from being dropped. No person shall deposit manure removed from the bins or pits within any of the more densely populated parts of the District without a permit from the health officer. Any person violating any of the provisions shall, upon conviction thereof, be punished by a fine of not more than $40 for each offense.

Not only must horse stables be cared for, but chicken yards, piggeries, and garbage receptacles as well. In cities, with better methods of disposal of garbage and with the lessening of the number of horses and horse stables consequent upon electric street railways, bicycles, and automobiles, the time may come, and before very long, when window screens may be discarded.

DISPOSAL OF MANURE IN RURAL AND SUBURBAN DISTRICTS.

The control of flies in rural and suburban districts offers a much more difficult problem. Here it is out of the question to remove all manure from the premises twice a week. The problem is rather to find some method of disposal or storage which will conserve the fertilizing value of the manure and at the same time prevent all flies from breeding or destroy such as do breed there.

With this idea in mind it has been recommended that stable manure be removed every morning and hauled out at once and spread rather thinly on the fields. This procedure is advisable from the point of view of getting the maximum fertilizing value from the manure. Immediate spreading on the fields is said largely to prevent the loss of plant food which occurs when manure is allowed to stand in heaps for a long time. This method will be effective in preventing the breeding of flies only if the manure is hauled out promptly every morning and spread thinly so that it will dry, since it is unfavorable for fly development in dessicated condition. Removal every three or four days will not be sufficient. Observations have shown that if manure becomes flyblown, and the maggots attain a fairly good size before the manure is scattered on the fields, they can continue their

development and will pupate in the ground. A further objection is that during the summer months, when fly breeding is going on most actively, the agriculturist is also busy and can seldom spare the time or the teams to carry out such a program regularly.

CHEMICAL TREATMENT OF MANURE TO DESTROY FLY MAGGOTS.

The general practice is, therefore, to remove manure and keep it in heaps located as a rule very near the stables. How can fly breeding be prevented in such accumulations? As a result of recent investigations it is now possible to point out two methods which are practical and effective.

The first is the treatment of the manure pile with chemical substances which will kill the eggs and maggots of the house fly. The Bureau of Entomology, in cooperation with the Bureau of Chemistry and the Bureau of Plant Industry, has conducted a series of experiments during the last two years in which a large number of chemicals were applied to infested manure and observations made not only on their efficiency in killing the maggots, but also as to their effect on the chemical composition and bacterial flora of the manure. The object was to find some cheap chemical which would be effective in destroying the fly larvæ and at the same time would not reduce the fertilizing value of the manure.

TREATMENT WITH HELLEBORE.

Of the numerous substances tried, the one which seems best to fulfill these conditions is powdered hellebore. Some of the powdered hellebore in use is prepared from the roots of a plant which botanists know as *Veratrum viride*, and which is popularly known as Indian polk or itch weed. It is common in wet grounds and is of wide distribution in the United States. The European species of this plant, *Veratrum album*, however, furnishes the bulk of the supply. Hellebore contains a number of chemical compounds known as alkaloids. Alkaloids are organic substances, of which quinine, morphine, and cocaine may be mentioned as examples, which act very intensely on the animal body. For the treatment of manure a water extract of the hellebore is prepared by adding ½ pound of the powder to every 10 gallons of water, and after stirring it is allowed to stand 24 hours. The stock mixture thus prepared is sprinkled over the manure at the rate of 10 gallons to every 8 bushels (10 cubic feet) of manure. From the result of 12 experiments with manure piles treated under natural conditions it appears that such treatment results in the destruction of from 88 to 99 per cent of the fly larvæ. Amounts of hellebore less than ½ pound to every 8 bushels of manure are not so effective, while stronger applications will, of course, give somewhat better results.

Bacteriological studies of the treated piles proved that the bacteria were not injured nor their development retarded, and chemical analysis showed that the composition of the manure was unaltered. Furthermore, several field tests were made in growing cabbages, turnips, lettuce, potatoes, wheat, and a few other crops on plats which had been fertilized with hellebore-treated manure, with the result that there appeared no injury whatever that could be ascribed to the use of this substance. The only possible objection to the use of hellebore seems to be the possibility of poisoning farm animals, as might happen if, for example, the barrel or tank in which the stock solution was prepared were left uncovered in an accessible place. It is quite safe to say that chickens will not be injured by pecking at hellebore-treated manure. This has been tested carefully. Hellebore can be obtained both in ground and powdered form, but the powdered form gives the best results in the destruction of fly larvæ. It costs from 12 to 16 cents per pound and under normal conditions can be obtained in large lots for 10 cents or less per pound. It is estimated that the cost of treating horse manure with hellebore will be a little over 1 cent for every 2 bushels. It will be of interest to the agriculturist to know that in applying hellebore to manure he is adding a substance which contains fully 1 per cent of nitrogen.

TREATMENT WITH POWDERED BORAX.

Another chemical found to be even more effective as a larvicide is powdered borax. This is an inorganic substance, available in commercial form in all parts of the country. It has the advantage of being comparatively nontoxic and noninflammable and is easily transported and handled. The minimum amount necessary to kill fly larvæ was found to be 0.62 pound per 8 bushels of manure, or about 1 pound per 16 cubic feet. Best results were obtained when the borax was applied in solution, or when water was sprinkled on after the borax had been scattered evenly over the pile. Borax is not only effective in killing the larvæ, but when it comes in contact with the eggs it exerts a toxic action which prevents them from hatching. When applied at the rate of 1 pound to 16 cubic feet it was found to kill about 90 per cent of the larvæ, heavier applications killing from 98 to 99 per cent.

Borax had no injurious effect on the composition of the manure; in fact, in some cases the ammonia and water-soluble nitrogen seemed to be increased; nor was there any permanent decrease in the number of bacteria. Borax-treated manure was less subject to the growth of molds and consequent firefanging. Now, although borax does not have any deleterious effect on the chemical composition of manure, yet when added to the soil with the manure it acts directly on plants,

and large applications will cause considerable injury. On the other hand, certain investigators have shown that small amounts of borax have a stimulating effect. The question is, therefore, whether any injury to plants will result from the application of manure treated at the rate of 1 pound per 16 cubic feet. To answer this point numerous tests were carried out, both in the greenhouse and under field conditions, using borax-treated manure for fertilizing a number of different crops, such as wheat, potatoes, peas, beans, lettuce, and others. As far as these experiments have gone they indicate that if manure so treated is applied at a rate of not more than 15 tons per acre no injury, as a rule, will follow. However, some plants are more sensitive to the presence of borax than others, and the effects are more noticeable on some soils than on others. All crops have not been tested, nor has the cumulative effect of borax treatment been worked out. It is necessary, therefore, to repeat the warning issued in connection with a previous bulletin on this subject, that great care should be exercised in the application of borax, so that the manure will never receive more than 1 pound for every 16 cubic feet and that not more than 15 tons of manure so treated should be applied to the acre.

THE BEST SUBSTANCE FOR TREATMENT OF MANURE INTENDED FOR USE AS A FERTILIZER.

In view of the possible injury from the borax treatment as a result of carelessness in applying it, or from other unforeseen conditions, it is to be recommended that horse manure and other farmyard manures which are to be used as fertilizer should be treated with hellebore. Borax, on the other hand, is such a good larvicide that it can be used with advantage on the ground of soil-floor stables, in privies, on refuse piles, and on any accumulations of fermenting organic matter which are not to be used for fertilizing purposes.

Of course there are a number of other insecticides which are effective against fly larvæ. Potassium cyanid, Paris green, arsenite of soda, etc., are effective, but they are hardly to be recommended for general use because of their extremely poisonous nature. Others, like pyridine, aniline, and nitrobenzene emulsion, are rather too expensive when used in amounts necessary to kill the maggots.

MAGGOT TRAP FOR DESTRUCTION OF FLY LARVÆ FROM HORSE MANURE.

The second method of handling manure is one which does not require the application of chemicals. It is based on the fact mentioned on page 7 that the larvæ of the house fly, when about ready to pupate, show a very strong tendency to migrate. They leave the spot where they have been feeding and crawl about in search of a suitable

place for pupation. This migration takes place mostly at night, and the larvæ sometimes crawl considerable distances away from the manure pile. Now it is possible by means of a very simple arrangement called a maggot trap to destroy fully 99 per cent of all maggots breeding in a given lot of manure. A successful maggot trap which the Maryland Agricultural College constructed at the college barn last year is shown in figure 14. The trap was designed by the junior author and constructed under his supervision. The manure, instead of being thrown on the ground, is heaped carefully on a slatted platform, which stands about 1 foot high. This particular platform meas-

FIG. 14.—A maggot trap for house-fly control. View of the maggot trap, showing the concrete basin containing water in which larvæ are drowned, and the wooden platform on which manure is heaped. (From Hutchison.)

ures 10 by 20 feet. There are six 2 by 4 pieces running lengthwise 2 feet apart. Across these are nailed 1-inch strips with ½ to 1 inch spaces between them. The wooden platform stands on a concrete floor, and a rim or wall of concrete 4 inches high surrounds the floor. The floor slopes a little toward one corner, from which a pipe leads to a small cistern near by. This pipe is plugged with a stopper of soft wood, and the concrete floor is filled with water to a depth of 1 inch in the shallowest part. The manure is then heaped on the platform each morning when it is removed from the stable. Flies will lay their eggs on the manure as usual, but the maggots, when they have finished feeding and begin to migrate, crawl out of the

manure, drop into the water below, and are drowned. Each week the plug is removed from the pipe, and all the maggots are washed into the cistern. The floor is then cleaned of any solid particles by means of a long-handled stable broom or by a strong stream of water from a hose. The pipe being again plugged, the floor is again partly filled with water and the trap is ready for another week's catch. A platform of this size will hold the manure accumulating from four horses during the period of four months, or about 20 days' accumulation from 25 horses, if the heap is well built and made at least 5 feet high.

Experience with maggot traps has brought out the following points: In the first place, the trap is more effective when the manure is kept compactly heaped and well moist. This is to be explained by the fact that the larvæ seek a comparatively dry place in which to

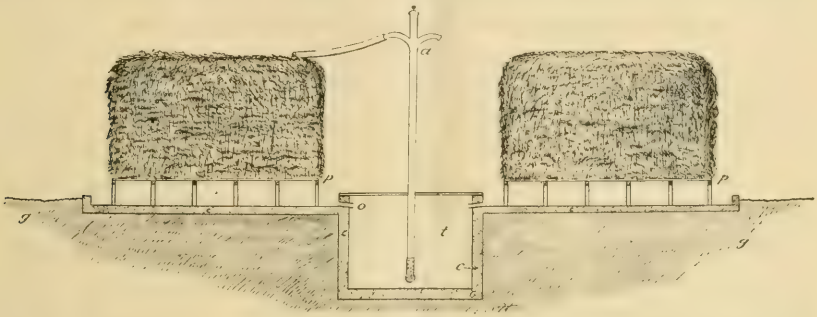

FIG. 15.—Imaginary cross section of an arrangement suggested for use where manure production is large. *a*, Pump; *c*, concrete floor and walls of cistern; *o*, outlet pipes leading from floor of maggot trap to cistern; *p*, platform maggot trap; *t*, cistern for liquid manure; *g*, ground level. (From Hutchison.)

pupate, and crawl away from wet manure. A cistern should be built close to the trap, and a pump fitted so that liquids can be pumped onto the heap. (Fig. 15.) Each day, after the litter from the stable has been thrown on the heap, just enough water should be added to moisten it thoroughly without causing leaching. The ideal arrangement would be to have water-tight floors in the stalls and drains leading to the cistern. The liquid manure collecting in the cistern could be pumped on the manure heap, thus not only maintaining the moisture content necessary to insure the greatest amount of migration, but also adding to the manure the valuable constituents of the urine. It happens, too, that keeping the manure carefully heaped and watered promotes the anaerobic fermentation and tends to prevent to some degree the loss of ammonia and gaseous nitrogen.

In the second place the platform should stand not less than 1 foot above the concrete floor. This is to facilitate cleaning the floor of maggots and the débris which unavoidably accumulates there. The

floor should be cleaned at least once a week, and all liquids run into the cistern, in order to prevent mosquitoes from breeding in the water in the floor of the trap. A thin film of oil can be used to prevent mosquito breeding in the cistern.

A third point of importance is that old manure is unfavorable for fly breeding. Experiments have shown that after manure has been standing on a maggot trap for eight to ten days it is practically free from maggots, and no more will appear in it. This means that a given lot of manure need remain on the maggot trap for only 10 days in order to prevent any breeding taking place in it.

The maggot trap is simple, easily constructed, and cheap. Practically the only cost is the initial one for the construction. Very little extra labor is required to operate it. Only a few minutes each day are necessary to water the manure after the stable cleanings have been added to the heap. Cleaning the floor to dispose of the maggots and to prevent mosquito breeding will take about half an hour once a week.

That the maggot trap is effective has been shown by the junior author's observations at the Maryland Agricultural College. It was found that the trap destroyed 99 per cent of the larvæ breeding there and that the number of flies at the barn and around the college kitchen was reduced from 67 to 76 per cent. That the reduction in the prevalence of flies was not equal to the percentage of larvæ destroyed was ascribed to the fact that several other piles of untreated manure were breeding out flies at near-by stables, from which places they were attracted to the barn and kitchen.

Maggot traps may be constructed in almost any size and to suit almost any conditions, and appear to be especially adapted to meet the problem of fly control under rural conditions.

TREATMENT OF MISCELLANEOUS BREEDING PLACES.

It is just as true under farm conditions as in cities that breeding places other than horse manure must be attended to. Garbage must be disposed of, hog and poultry manure must be cared for, and especially on dairy farms it is extremely important that every precaution be taken to prevent the contamination of milk by flies. Care and cleanliness, combined with some of the arrangements just described, will measureably affect the fly nuisance in neighboring buildings.

SEWAGE DISPOSAL IN RELATION TO THE PREVENTION OF FLY-BORNE DISEASES.

In the consideration of these measures we have not touched upon the remedies for house flies breeding in human excrement. On account of the danger of the carriage of typhoid fever, the dropping of human excrement in the open in cities or towns, either in vacant

lots or in dark alleyways, should be made a misdemeanor, and the same care should be taken by the sanitary authorities to remove or cover up such depositions as is taken in the removal of the bodies of dead animals. For modern methods of sewage disposal adapted for farm use one should consult Department Bulletin No. 57, which may be obtained from the Superintendent of Documents for 10 cents. In the absence of modern methods of sewage disposal absolutely sanitary privies are prime necessities, whether in towns or on farms. Directions for the building and caring for such privies will be found in Farmers' Bulletin No. 463. The box privy is always a nuisance from many points of view, and is undoubtedly dangerous as a breeder of flies which may carry the germs of intestinal diseases. The dry-earth treatment of privies is unsatisfactory. No box privy should be permitted to exist unless it is thoroughly and regularly treated with some effective larvicide. Since the fecal matter in such privies is seldom used for fertilizing purposes it may well be treated liberally with borax. The powdered borax may be scattered over the exposed surface so as to whiten it. An application two or three times a week during the fly season ought to prevent all fly breeding in such matter.

WHAT COMMUNITIES CAN DO TO ELIMINATE HOUSE FLIES.

Antifly crusades have been very numerous in recent years, and some have been noteworthy both as to methods and results. However, it will not be amiss here to emphasize the importance of concerted, organized effort on the part of whole communities, not only cities, but suburban and rural neighborhoods as well. By the most painstaking care one may prevent all fly breeding on his premises, but it will avail him little if his neighbors are not equally careful. Some sort of cooperation is necessary. One of the first and most important elements in any antifly crusade is a vigorous and continued educational campaign. It has been the experience of those who have undertaken such crusades that people generally regard the fly as a somewhat harmless nuisance and that the first work of the campaign was to bring the people to a realization of the dangers from flies and the possibility of getting rid of them. In the educational campaign every possible means of publicity can be employed, including newspapers, lectures, moving pictures, posters, handbills, cartoons, instruction in schools, etc.

The antifly crusade is a matter of public interest and should be supported by the community as a whole and engineered by the health officers. But health officers can do little toward the necessary work of inspection and elimination without funds, and therefore the support of the campaign must manifest itself in increased appropriations

for public-health work. The example of York Village, Me., is one to be emulated. The appropriation for health work in that city amounts to about $1 per capita per year—the largest per capita expenditure for public-health work of any community in the United States. Very often it is lack of funds which prevents the health officers from taking the initiative in the antifly crusades, and there must necessarily be much agitation and education before they can profitably take up the work. Right here lies a field for civic associations, women's clubs, boards of trade, etc., to exercise their best energy, initiative, and leadership.

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FARMERS' BULLETIN

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE SILVERFISH;[1] AN INJURIOUS HOUSEHOLD INSECT.

By C. L. MARLATT,
Entomologist and Acting Chief in Absence of Chief.

INTRODUCTION.

The silverfish (fig. 1) is often one of the most troublesome enemies of books, papers, card labels in museums, and starched clothing, and occasionally of stored food substances. Its peculiar fishlike form and scaly, glistening body, together with its very rapid movements and active efforts at concealment whenever it is uncovered, have attached considerable popular interest to it and have resulted in its receiving a number of more or less descriptive popular names, such as silverfish, silver louse, silver witch, sugarfish, etc. The species named above is the common one in England, but it also occurs in this country, and, like most other domestic insects, it is now practically cosmopolitan. It has a number of near allies, which closely resemble it, both in appearance and habits. One of these, (*Lepisma*) *Thermobia domestica* Pack., has certain peculiarities of habit which will be referred to later. The unusual appearance of the common silverfish early drew attention to it, and a fairly accurate description of it, given in a little work published in London in 1665 by the Royal Society, is interesting enough to reproduce:

FIG. 1.—The silverfish (*Lepisma saccharina*): Adult. Enlarged. (Original.)

It is a very small, silvery, shining worm or moth which I found much conversant among books and papers, and is supposed to be that which corrodes and eats holes

[1] *Lepisma saccharina* L. Thysanura, family Lepismatidæ.

NOTE.—This bulletin is of special interest to housekeepers throughout the United States. It is a revision of Circular No. 49 of the Bureau of Entomology, U. S. Department of Agriculture.

through the leaves and covers. It appears to the naked eye a small, glittering, pearl-colored moth, which upon the removing of books and papers in the summer, is often observed very nimbly to scud and pack away to some lurking cranny where it may better protect itself from any appearing dangers. Its head appears big and blunt, and its body tapers from it toward the tail, smaller and smaller, being shaped almost like a carret.[1]

HABITS AND INJURY.

On account of its always shunning the light and its ability to run very rapidly to places of concealment, it is not often seen and is most difficult to capture, and being clothed with smooth, glistening scales, it will slip from between the fingers and is almost impossible to secure without crushing or damaging. It is one of the most serious pests in libraries, particularly to the binding of books, and will frequently eat off the gold lettering to get at the paste beneath, or, as reported by the late P. R. Uhler, of Baltimore, often gnaws off white slips glued on the backs of books. Heavily glazed paper seems very attractive to this insect, and it has frequently happened that the labels in museum collections have been disfigured or destroyed by it, the glazed surface having been entirely eaten off. In some cases books printed on heavily sized paper will have the surface of the leaves a good deal scraped, leaving only the portions covered by the ink. It will also eat any starched clothing, linen, or curtains, and has been known to do very serious damage to silks which had probably been stiffened with sizing. Its damage in houses, in addition to its injury to books, consists in causing the wall paper to scale off by its feeding on the starch paste. It occasionally gets into vegetable drugs or similar material left undisturbed for long periods. It is reported also to eat occasionally into carpets and plush-covered furniture, but this is open to question.

STRUCTURE AND RELATIONSHIPS.

The silverfish belongs to the lowest order of insects—the Thysanura—is wingless, and of very simple structure. It is a wormlike insect about one-third of an inch in length, tapering from near the head to the extremity of the body. The head carries two prominent antennæ, and at the tip of the body are three long, bristle-shaped appendages, one pointing directly backward and the other two extending out at a considerable angle. The entire surface of the body is covered with very minute scales like those of a moth. Six legs spring from the thorax, and, while not very long, they are powerful and enable the insect to run with great rapidity.

In certain peculiarities of structure, and also in their habits, these anomalous insects much remind one of roaches, and their quick, gliding movements and flattened bodies greatly heighten this resemblance. More striking than all, however, is the remarkable development of the coxæ or basal joints of the legs in the silverfish, which

[1] Hooke, R., Micrographia, p. 208-210. London, 1665.

finds its counterpart in roaches, and, taken in connection with the other features of resemblance, seems to point to a very close alliance between the two groups, if, indeed, the silverfish are not merely structurally degraded forms of roaches and to be properly classed with the Blattidæ.

ANOTHER COMMON SPECIES.

Another common silverfish of this country, referred to in the opening paragraph, has developed a novel habit of frequenting ovens and fireplaces, and seemingly revels in an amount of heat which would be fatal to most other insects. It disports itself in numbers about the openings of ranges and over the hot bricks and metal, manifesting a most surprising immunity from the effects of high temperature. This heat-loving or bakehouse species (fig. 2) was described in 1873 as *Lepisma domestica* by Packard, who reported it to be common about fireplaces at Salem, Mass. This species is also very abundant in Washington. What is evidently this same insect began to be noted commonly about 1895 in England and on the Continent, where it manifests the same liking for hot places exhibited by it in this country. The habit of this species of congregating in bakehouses and dwellings, about fireplaces and ovens, has given rise to the common appellation in England of "fire-brat." Similar descriptive names are applied to it also on the Continent. This species closely resembles the common silverfish in size and general appearance, but may be readily distinguished from it by the presence on the upper surface of dusky markings. It also possesses well-

FIG. 2.—The "fire-brat" (*Thermobia domestica*): Adult female. Enlarged. (Original.)

marked structural differences, which have led to its late reference to a distinct genus—Thermobia. An Italian entomologist, Rovelli, has described this insect under the descriptive name *furnorum*, from its inhabiting ovens, and the name of the genus to which it is now assigned by English entomologists is also descriptive of its heat-loving character. A Dutch entomologist, Oudemans, reports that he has found it in abundance in all bakehouses that he has examined in Amsterdam, where it is well known to bakers and has received a number of familiar names.

REMEDIES.

Advantage may be taken of the liking of these insects for fabrics and other articles containing starch to poison them by slipping into all the crevices where they occur—in bookshelves and backs of mantels, under washboards, and in the bottoms of drawers—bits of cardboard on which a thin boiled starch paste poisoned with from 3 to 5 per cent powdered white arsenic has been spread and dried. The arsenic should be added to the flour and sufficient water used to make a thin paste by boiling. One of our correspondents reports complete relief by this measure.

The silverfish readily succumbs to pyrethrum, and wherever this can be applied, as on bookshelves, it furnishes one of the best means of control.

Sodium fluorid,[1] now recognized as one of the most efficient roach powders, will doubtless also be equally effective against silverfish. Where such course is possible it may be dusted by hand or with a powder blower in the situations where silverfish occur.

For starched clothing and similar objects liable to injury by it, frequent handling and airing and the destruction by hand of all specimens discovered is to be recommended, in addition to the remedies noted above. Little damage is likely to occur in houses except in comparatively moist situations or where stored objects remain undisturbed for a year or more.

[1] Marlatt, C. L. Cockroaches. U. S. Dept. Agr., Farmers' Bulletin 658, 15 p., 5 fig., 1915. Reference to sodium flourid against roaches, p. 12.

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

FLEAS AS PESTS TO MAN AND ANIMALS, WITH SUGGESTIONS FOR THEIR CONTROL.

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INTRODUCTION.

Fleas are of importance to man in two ways: First, as disease carriers and, second, as parasites or annoyers of man and animals. The dread disease of man known as bubonic plague has been found to be transmitted largely, if not entirely, through the agency of these insects. A disease known as infantile kala azar, occurring in the countries bordering the Mediterranean Sea, is probably also transmitted by them, and a species of tapeworm which infests dogs and occasionally people has been found to pass at least one stage in the dog flea, then gaining entrance to a new host by the swallowing of crushed or living fleas. As parasites of man and animals fleas are of considerable importance aside from disease transmission. In many instances they have been known to render houses uninhabitable for a time, and certain species cause considerable loss among poultry as well as annoyance to other animals.

LIFE HISTORY AND HABITS OF FLEAS.

It should be borne in mind that there are a great many different kinds of fleas. Most of these are of no importance to man, as they feed on various wild birds and mammals. Nearly all species have some one host upon which they prefer to live, but they may feed upon other animals and often thrive upon them.

As examples may be cited the dog flea (fig. 1),[1] which normally feeds on dogs and cats, but which when excessively numerous may prove a troublesome pest to man. The human flea normally attacks man, but may be found on a number of other animals. Rat fleas, in the absence of their usual hosts, will bite man, and it is in this instance that fleas are responsible for the inoculation of man with bubonic plague.

There is a marked variation in the habits of fleas in regard to the intimacy with which they are associated with their hosts. Some kinds remain upon host animals practically all of the time. In fact, the chigoe flea normally buries itself in the skin of the host and there develops its eggs and dies. The sticktight flea, or chicken flea, has this habit of intimate association with the host, but does not bury itself in the flesh of the animal. Dog fleas ordinarily remain upon the domestic animals almost continuously throughout their existence, but are not attached, feeding only at intervals. The human flea has adapted itself to its host so closely that it remains upon man but little, being free the greater portion of the time.

There are four different stages in the life of fleas, as is the case with many other insects: these are the egg, larva, pupa, and adult.

A number of eggs are deposited by each adult flea. The egg laying, alternated with feeding, extends over a considerable period of time. In most cases the ova are deposited by the fleas while the latter are on the host, but as they usually are not cemented to the hair or feathers they fall out in the nest or resting place of the animal. The eggs are white or cream in color and ovoid in shape. Large numbers of them may often be seen on mats or cushions upon which infested dogs or cats sleep. Especially are they easily observed when on dark-colored cloths. The egg of the common dog flea is illustrated in figure 1 at *a*. Hatching usually takes place in from 2 to 12 days.

The larva when first hatched is very minute, of whitish color, and quite active. (See fig. 2, larva of European rat flea.) In this stage none of the fleas is parasitic. They depend upon various animal and vegetable débris, including the excrement of the adult fleas, for food. During their growth the skin is shed two or three times, and between four days and several months after hatching a silken cocoon is spun, and in this the larva transforms to the pupal or resting stage. (See fig. 1, *b* and *c*, pupa of dog flea.)

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[1] The fleas mentioned in this bulletin are known scientifically as follows: Dog flea, *Ctenocephalus canis* Curtis; cat flea, *Ctenocephalus felis* Bouch.; human flea, *Pulex irritans* L.; rat fleas, *Xenopsylla cheopis* Roth. (the Indian rat flea), *Ceratophyllus fasciatus* Bosc. (the European rat flea), and others; chigoe, *Dermatophilus penetrans* L.; sticktight or chicken pox flea, *Echidnophaga gallinacea* Westw.

The insect remains within the cocoon for a period which may range from three days to more than a year. The cocoon of the dog flea is illustrated in figure 1 at *b*. The dark curved object within is the larva just before pupating.

The complete life cycle of members of this group of insects may be passed in as short a period as 19 days, but during cool weather

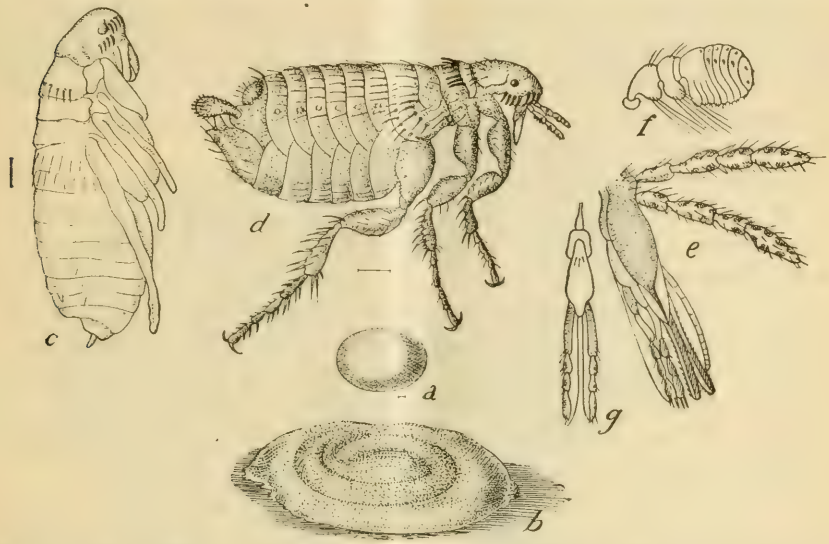

FIG. 1.—The dog flea: *a*, Egg; *b*, larva in cocoon; *c*, pupa; *d*, adult; *e*, mouth parts of same from side; *f*, antenna; *g*, labium from below. *b*, *c*, *d*, Much enlarged; *a*, *e*, *f*, *g*, more enlarged. (From Howard.)

or under adverse conditions the total period from egg to adult may extend considerably over a year.

HOW LONG THE ADULT WILL LIVE.

The length of life of the mature flea varies much in different species and also under different atmospheric conditions. During

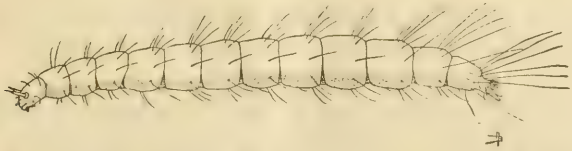

FIG. 2.—The European rat flea: Larva. Greatly enlarged. (Author's illustration.)

hot, dry weather, and when no animals upon which to feed are present, the duration of life is exceedingly short—two to five days When allowed to feed on blood, which is the only food taken by the adults, they may live from a month to almost a year. During sum-

mer probably the average longevity of the human flea without food is about two months, of the dog flea somewhat less, and of the stick-tight flea still less.

ABUNDANCE OF FLEAS IN RELATION TO SEASON, CLIMATE, AND OTHER CONDITIONS.

In the northern part of the United States nearly all fleas pass the winter in the immature stages, while in the more southern latitudes some of them are present on hosts throughout the winter months. In general, however, these insects are never as abundant during winter and spring as they are in summer and fall.

Rainfall and the amount of moisture in the atmosphere have much to do with flea breeding. As a rule rainy summers are productive of outbreaks of fleas, and extremely hot, dry weather tends to check their breeding. This condition is brought about by the fact that the larva and pupa require a certain amount of moisture for successful development, and the adults also live longer when there is a proper degree of moisture present. It is not intended to convey the idea that fleas require very moist places in which to breed. As a matter of fact, excessive moisture in the breeding places is as detrimental as excessive dryness.

It is common knowledge that fleas occur in greatest abundance in sandy regions. This is explained by the fact that the sand maintains a more uniform moisture condition and thus permits the immature stages of the flea to develop with greater success. The sand also offers some protection to the adults and renders heavy rains less destructive to all stages of the flea present on the soil.

FLEAS AS PESTS IN THE HOUSEHOLD.

As has been pointed out,[1] in the eastern part of the United States the dog flea is the species of greatest importance as a household pest. Many instances have been brought to the attention of the Bureau of Entomology in which houses, particularly those vacated for some time during the summer months, have been found to be literally overrun by these pests.

In portions of the South and West the human flea (figs. 3 and 4) is the one primarily responsible for house infestations. Although the host relationship of these two species is somewhat different, the same methods of control are applicable, for the most part, to both.

[1] Howard, L. O. House Fleas. U. S. Dept. Agr., Bur. Ent., Cir. 108, 4 p., 2 fig., Feb. 11, 1909.

The conditions which give rise to outbreaks in houses, particularly in the case of the dog flea, are usually these: Pet dogs or cats are kept about the household during the spring and early summer, and great numbers of eggs are deposited upon them by the fleas. These eggs are scattered about the floors and soon hatch into minute maggots which feed upon the vegetable and animal matter under carpets and mattings and in cracks. During this time the house has been closed up and the breeding allowed to proceed unmolested, so that at about the time the occupants return the fleas have reached

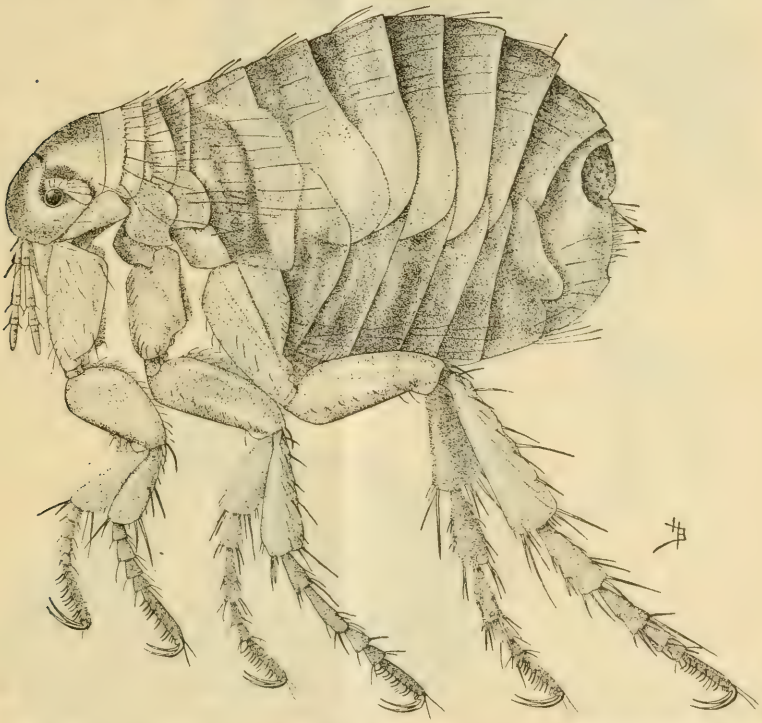

FIG. 3.—The human flea: Adult female. Greatly enlarged. (Author's illustration.)

the adult stage. In the absence of other hosts they are exceedingly hungry and ready to attack man or any animals which are accessible.

Some infestations of residences come from breeding places beneath the houses. The fleas in these cases are usually furnished by stray animals which sleep under the buildings. The immature stages develop in the accumulation of dust and vegetable matter in the beds of these animals. Instances are not uncommon where such infestations may extend to lawns, barnyards, and, in fact, all over the premises, although as a rule the center of infestation is in some one definite place frequented by animals.

The infestations of the human flea are usually less heavy than in the extreme cases above mentioned, and the breeding places are often more widely extended.

A number of instances in the Southern and Central-Western States have come to notice where hogs appear to have been the source of gross infestations of the human flea. The adult fleas feed on the hogs, and breeding takes place in the beds of these animals. In some

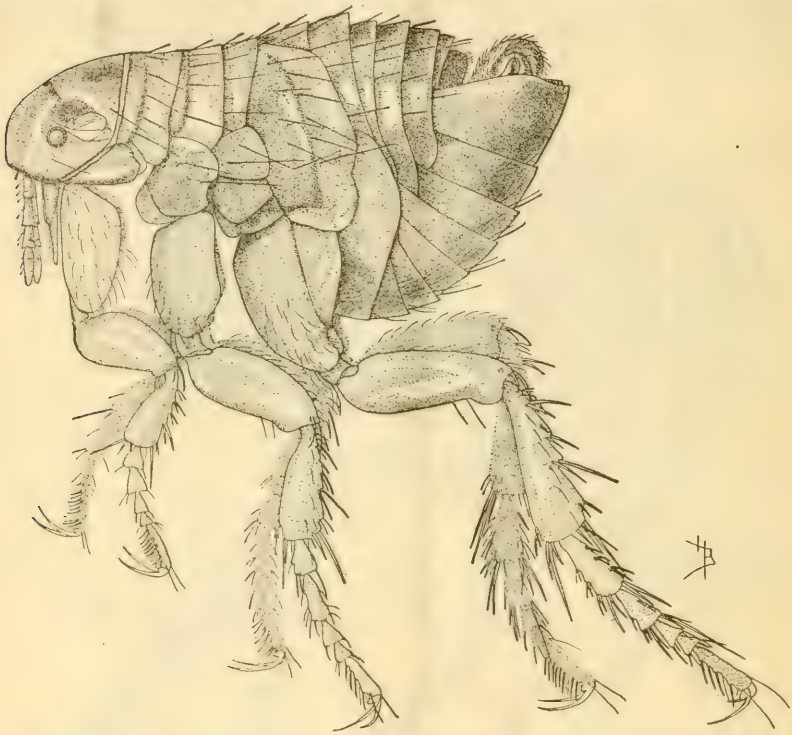

FIG. 4.—The human flea: Adult male. Greatly enlarged. Note the difference in the shape of the abdomen of the male as compared with that of the female (fig. 3). (Author's illustration.)

instances the source of infestation is in the hog runs, but more usually it is derived from hogs sleeping under houses.

FLEAS INJURIOUS TO POULTRY AND DOMESTIC ANIMALS.

Fortunately the higher domestic animals are comparatively free from flea attacks. Horses, cattle, sheep, and goats are very seldom annoyed, although a few instances have come to our attention in which the sticktight flea infested horses. Hogs are infested to some extent, but seldom heavily enough to do any damage.

THE STICKTIGHT FLEA.

The sticktight flea, or southern chicken flea, is probably the most important of our live-stock infesting species. This form attacks a number of different hosts, including poultry, dogs, cats, and some wild animals. As has been stated, the adult fleas remain during the greater part of their lives attached to the host animal. On dogs and cats they are largely found on the ears, particularly along the edges. In the case of poultry infestations fleas are most common on the heads of the hosts, where they are to be seen in groups or patches. This habit of attaching in clusters seems to be well marked, and an infested fowl often may be recognized at a considerable distance by the dark flea-covered areas about the eyes, comb, and wattles. Figure 5 illustrates the usual mode of infestation on a chicken's head, and figure 6 shows one of the fleas much enlarged. When the fleas are excessively abundant they may be found in similar patches on the neck and various parts of the body.

FIG. 5.—Head of rooster infested with the sticktight flea. Somewhat reduced. (Author's illustration.)

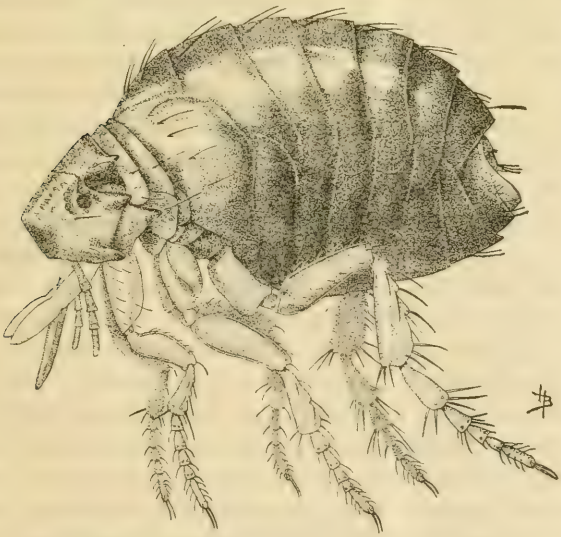

FIG. 6.—The sticktight flea: Adult female. Much enlarged. (Author's illustration.)

This flea is most common and of greatest importance in the Southern and Southwestern States. It has been reported as injurious to poultry as far north as Kansas. The injury is most marked in young chickens, which when fairly heavily infested often die

quickly. Older fowls are more resistant, but have been known to succumb to very heavy infestations; and certainly the fleas materially reduce egg production, retard the growth of fowls, and diminish their size.

The eggs are deposited by the adult flea while it is attached to the host. They fall to the ground under the roost in chicken houses or under sheds frequented by the poultry and there continue to develop. When dogs and cats are infested the immature stages develop largely in the material used by them for beds.

A few other species of fleas are occasionally found in poultry houses. Some of these may be normally bird-infesting species, while others are at home in the houses of domestic poultry. Infestations by these fleas have been reported from several places in the Northern States, particularly in the Northwest. The presence of the fleas is usually first detected by the adults getting on the bodies of persons entering chicken houses. These fleas do not remain attached to the host continuously as does the sticktight flea. They are seldom of any great importance and may be controlled by the same methods outlined on pages 13 and 14.

DOG AND CAT FLEAS.

Dogs and cats are infested by two very closely related species of fleas,[1] and these appear to feed more or less interchangeably on the two hosts, as well as occasionally on man and other animals. While they cause these hosts much annoyance and, as has been pointed out, are also responsible for the infestation of dogs by tapeworms, serious injury seems to be rare. However, in the case of valuable dogs and cats it is often desirable to rid them of fleas, and in all cases where these animals are closely associated with man the control of the fleas upon them is of importance. As will be seen by comparing figure 1 with figure 6, the dog flea is quite different from the sticktight flea in structure as well as in size. The adults do not remain attached to the host in one place, but the life history is not vastly different from that of the sticktight flea. Breeding takes place in similar materials in situations occupied by the host animals. Mr. Theodore Pergande, working with the dog flea at Washington, D. C., found the life cycle from egg to adult to be completed within 17 to 37 days. It is thus seen that a great number of fleas might be bred in and beneath an unoccupied house in a comparatively short period.

Both of these species have a very wide distribution, being found in practically all parts of the world where dogs and cats are found.

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[1] The cat flea is known scientifically as *Ctenocephalus felis* Bouché, and the dog flea as *Ctenocephalus canis* Curtis. The human flea also is not uncommonly found on dogs and cats.

FLEAS IN RELATION TO BUBONIC PLAGUE.

During recent years bubonic plague has been introduced into the United States on both the Pacific and Gulf coasts. The infestation in California persisted for a number of years, although it was closely held in check through the efforts of the Public Health Service and the State board of health. The disease around San Francisco not only persisted among the rats, but gained a foothold among ground squirrels in the counties adjacent to San Francisco Bay. A strenuous fight is being waged against rats in all of the Pacific ports and against ground squirrels in the territory where the disease has become established among these rodents.

During the year 1914 the disease broke out in New Orleans, but strict quarantine measures and an energetic campaign against the rats kept the malady from spreading and limited the number of human cases.

While the plague situation is now well in hand it is important that all have a general knowledge of the essential steps in controlling the disease. The prevention of the introduction of bubonic plague depends to a considerable extent upon quarantine regulations at our ports of entry, but it is of even greater importance that united effort be put forth to control the rats in the seaport towns. The work should not stop here, as it is of importance that concerted action be taken against rats and ground squirrels throughout the entire country.

It may be gathered from what has been said that the control of bubonic plague depends almost entirely upon the destruction of the rat population. This is essential in that the disease always starts by gaining a foothold among the rats, and as these animals die and the fleas leave them and attack man the human cases of plague begin.

In addition to the importance of rat control from the standpoint of disease prevention there is every reason to wage war against these pests on account of their importance as destroyers of agricultural and other products. It has been estimated that the loss in the United States due to rats exceeds $100,000,000 annually. The principal methods of combating these rodents[1] are rat proofing, trapping, poisoning, and destruction by natural enemies.

With the reduction in numbers of rats and mice the various species of fleas which infest them and which in turn may play a part in carrying bubonic plague are greatly reduced in numbers. The cleaning up of the breeding places of rats and the destruction of their nests will also accomplish the extermination of a large number of fleas in the immature stages. Some of the methods of trapping fleas mentioned under "Means of Repression" will aid in destroying these

[1] The methods of rat control are discussed in Farmers' Bulletin 369, U. S. Department of Agriculture, by Mr. D. E. Lantz, of the Bureau of Biological Survey.

which may have fed on rats and are therefore dangerous as regards disease transmission.

Persons resident in districts where plague occurs among the ground squirrels should remember that there is danger of infection from the bites of fleas which infest these animals.

MEANS OF REPRESSION.

Certain general principles regarding the control of fleas are applicable to nearly all species, but some modifications of the methods employed are necessary for different species and under the different conditions in which they exist.

METHODS OF COMBATING HOUSEHOLD INFESTATIONS.

As has been pointed out, the dog flea and the human flea are the two most important species invading the habitations of man. It has also been suggested that the adult fleas feed more or less on cats and dogs and that the immature stages develop in the cracks of floors and beneath houses. It is at once apparent that two steps are necessary to cope with the pest: (1) The destruction on the host of the adults which are producing the eggs, and (2) the clearing out of the immature stages which are breeding in or under the house.

THE DESTRUCTION OF FLEAS ON CATS, DOGS, AND HOGS.

One of the most successful methods of killing fleas on cats and dogs is to wash the animals thoroughly in a tub containing the proper proportion of a saponified coal-tar creosote preparation, of which there are a number on the market, known as "stock dips," etc. The animal should be thoroughly scrubbed, making sure that the fleas on the head are well soaked, as many rush there to get away from the parts that are covered with the solution. After the animal has been in the bath for about 5 or 10 minutes it may be removed and allowed to dry. In the case of cats, especially if tender skinned, the preparation may be washed out of the fur with soap and warm water soon after the animal is taken out of the solution.

In addition to the destruction of all fleas present, this accomplishes the cleansing and deodorizing of the fur and also aids in the healing of any wounds which are present.

Other methods of destroying fleas on cats and dogs have been recommended. Among these the careful rubbing into the hair of powdered naphthalene or moth balls has been found effective. Pyrethrum or Persian insect powder is used in the same way. Both of these materials stupefy the insects and cause them to come to the

surface of the hair or actually drop out. The animals should be treated on papers spread on the floor and the insects burned after the dusting is completed.

Fleas on hogs may be destroyed by dipping the animals in a vat containing some of the creosote dips as used for the hog louse or by sprinkling crude petroleum on them when they are eating.

CONTROL OF HOSTS.

In order to avoid the infestation of houses, it is important to keep all animals from beneath dwellings. In such situations breeding may progress rapidly, and it is very difficult to treat the breeding places. If fleas are continuously annoying about the household, it is often desirable not to admit cats and dogs at all, but to provide regular sleeping quarters for these animals out of doors and prevent flea breeding by methods suggested in the following paragraph. Stray cats and dogs should not be encouraged about the premises. In towns and cities the enforcement of the dog-tax law and the destruction of all untagged animals will tend greatly to reduce house infestations. It is also desirable to keep different kinds of animals which are subject to flea infestation separated, and care should be exercised that infested animals are not brought to clean premises and that infested poultry are not placed with a clean flock.

DESTRUCTION OF FLEAS IN IMMATURE STAGES.

Following the ridding of infested animals of adult fleas, it is important to destroy the immature ones which are constantly becoming full grown and reinfesting animals and annoying man. In household infestations it is usually found that the breeding takes place in the cracks of floors or beneath carpets or in rooms which are not frequently swept, but which may be visited by pet dogs and cats. The carpets and rugs should be removed, the floors thoroughly swept, and all of the dust thus obtained burned, as it contains many of the eggs and maggots of the fleas. The floor should then be scrubbed with strong soapsuds or sprinkled with gasoline, taking care to avoid having fires about during this procedure. After the floor coverings are thoroughly aired and beaten they may be returned, but it is desirable before putting them down to sprinkle the floor with naphthalene crystals or pyrethrum powder.

In flea-infested regions it is advisable to avoid the use of mattings and carpets. These may be supplanted by rugs or oiled bare floors. This permits frequent sweeping of the floors and makes the destruction of the immature stages easier if an infestation becomes established.

Among other methods for destroying the fleas in houses the following have been tried and recommended: Scatter 5 pounds of flake naphthalene over the floor of an infested room and close tightly the doors and windows for 24 hours. After this time the naphthalene may be swept into another room, and so on, thus making the treatment inexpensive. The free use of alum, both in the powdered form sprinkled over carpets and rugs and by dipping papers in an alum solution and placing them under the rugs, is said to give satisfactory results. The fumigation of houses with sulphur fumes or hydrocyanic-acid gas also accomplishes complete destruction. In addition to killing all of the fleas, rats and mice are destroyed by these last-mentioned methods. In using sulphur the infested building should be closed up tightly and the material used at the rate of 4 pounds to each 1,000 cubic feet of space. If the immature stages have been destroyed by the methods mentioned above, 2 to 3 pounds of sulphur per 1,000 cubic feet of space will be sufficient to destroy the adults. The sulphur is made into a cone shape in a good-sized pan or kettle and placed in a larger pan containing water to avoid danger of fire from the heat generated. A little alcohol is then poured into a depression made in the top of the cone of sulphur, and a match applied. Each room should have a pan of sulphur, and the rooms should be kept closed about 12 hours. As the gas generated corrodes metals and injures plants, it is necessary to remove metal objects and potted plants before fumigating. It is not advisable for anyone to undertake the use of hydrocyanic-acid gas without obtaining the complete directions for its employment as outlined in Farmers' Bulletin 699, entitled "Hydrocyanic-Acid Gas Against Household Insects." This gas is very poisonous, but is one of the most satisfactory for destroying all sorts of vermin in buildings.

When house infestations are derived from fleas which breed beneath or around houses the first step is to clean out all the loose material in which fleas may be breeding and burn it, and then to use crude petroleum freely about the breeding places. This may be followed by scattering common salt about and thoroughly wetting it down. The free use of lime on the cleaned areas also apparently destroys many immature fleas. In exceptional cases lawns become infested, and fleas breed out around the roots of the grass. It is impracticable to apply chemicals in such situations, but much may be done to check the breeding by cutting the grass exceedingly short and thus exposing the young fleas to the heat of the sun, which will usually accomplish their destruction. In certain sections it has been found feasible to destroy flea infestations in barns and hog runs by diking the infested areas and pumping water in so as to flood them entirely.

TRAPPING.

Following the treatment of host animals and the thorough cleaning up of the premises, as has been outlined, many of the remaining adult fleas may be caught by the use of traps.

There seems to be some virtue in the use of lights at night for attracting the adult fleas. A small lamp set in a pan of water covered with a film of kerosene may be used for this purpose.

It has been found that a considerable number of fleas may be collected about a room or cellar by allowing an animal such as a guinea pig or cat to be free in the room. The fleas thus concentrated on the animal may be destroyed by the methods mentioned under "The destruction of fleas on cats, dogs, and hogs." In districts where the plague is known to exist and it is desirable to catch the few fleas which may be about the premises, this method is of some value.

ISOLATING AND REPELLING.

It has been determined that the greatest horizontal distance fleas can jump is about 13 inches, and they can not jump more than one-half of this distance vertically. It is therefore possible to prevent them from gaining access to a bed by placing sticky fly paper about 13 inches wide on the floor around the bed, provided fleas are not breeding out under it. By keeping the bedding from reaching near the floor it is also possible to keep fleas out by placing the legs of the bed in a pan of water covered with a film of kerosene.

Many different substances have been advocated as repellents for fleas. Among these may be mentioned such plants as pennyroyal, and boughs and chips of pine. Naphthalene crystals and pyrethrum have also been employed for dusting between the sheets in order to repel the fleas from bedding, and these substances, as well as oil of pennyroyal and oil of tar, may be used about the household to drive out the fleas.

It should be borne in mind that the methods of trapping and repelling just discussed are only secondary to the more important measures of destroying the breeding places and freeing hosts from fleas.

METHODS OF CONTROLLING THE STICKTIGHT OR CHICKEN FLEA.

Many of the suggestions for controlling fleas in the household are applicable to the sticktight flea. As has been pointed out, this species breeds largely in chicken houses and adjacent buildings frequented by the fowls, although dogs and cats may be important sources of infestation.

As a preliminary step it is well to see that the poultry are kept away from other animals as far as possible. Especial care should be exercised to keep dogs and cats from lying about the chicken yards or places frequented by the poultry. All animals, and the poultry as well, should be excluded from beneath houses and barns, as such places are favorable for flea development and difficult to treat if they become infested. These precautions should be followed by a thorough cleaning out of the chicken house and outbuildings frequented by the poultry. All of the material should be hauled to a good distance from the buildings and scattered out. The places where the fleas are thought to be breeding should then be sprinkled with crude oil. One of the most satisfactory methods of preventing breeding is to scatter salt freely about the chicken house and then wet the soil down thoroughly. This species can not thrive in damp places, and if the sprinkling is done two or three times a week no further breeding is possible. If salt is used, due care should be taken to prevent the fowls from devouring it on account of its poisonous qualities.

It is rather difficult to destroy the sticktights on the poultry without injuring the host. It is desirable, however, in the case of heavy infestations to destroy as many of the fleas as possible. This may be accomplished by carefully applying carbolated vaseline to the clusters of fleas on the fowls or greasing them with kerosene and lard—one part kerosene to two parts lard. In all cases care should be taken when applications are made not to get the material on the poultry except on the seat of infestation. It is important that dogs and cats be freed from sticktight fleas. This may be accomplished by washing them in a saponified coal-tar creosote preparation, as has been described, or many of the insects may be killed by greasing the most heavily infested parts with kerosene and lard. Rats sometimes harbor these fleas in considerable numbers, therefore their destruction will aid in the control work as well as do away with another troublesome chicken pest.

The thorough cleansing of poultry houses and runs and the application of crude petroleum will be found to aid in the control of other important enemies of fowls, such as mites and chicken ticks or "blue bugs."

TREATMENT OF FLEABITES.

In regions in the United States where the plague is not known to occur no special concern need be felt regarding fleabites. When feeding, the fleas inject a salivary secretion which tends to produce inflammation at the site of the puncture. Usually the bites result in small inflamed spots, but occasionally, where the pests are very numerous and in cases where individuals are susceptible to the effect

of the bites, more general inflammation may occur, sometimes followed by swelling and occasionally, especially after scratching, by ulceration.

Those who are especially annoyed by the bites will find that various cooling applications will give relief. A 3 per cent solution of carbolic acid in water applied to the bites will be beneficial, and such substances as menthol, camphor, and carbolated vaseline will be found to allay the irritation. Iodine in the form of a tincture, if applied to the bites, will alleviate the irritation, but should not be used by persons afflicted with any form of eczema or applied to the tender skin of young children, as it may stimulate the eczemic eruptions or blister the skin, causing undue annoyance.

PUBLICATIONS OF UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO INSECTS AS PESTS TO MAN AND DOMESTIC ANIMALS.

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FARMERS' BULLETIN

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

GRASSHOPPERS AND THEIR CONTROL ON SUGAR BEETS AND TRUCK CROPS.

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INTRODUCTION.

Grasshoppers may injure crops in many parts of the United States, although the area having an annual rainfall of less than 25 inches is more subject to their attacks. This includes the country lying west of the Mississippi River, with the exception of a strip from 100 to 200 miles wide bordering that river, and a portion of the northern Pacific States. In the eastern part of the semiarid region about equal damage is done to upland and lowland crops. Farther west the absence of upland vegetation formerly confined the insects to the bottoms along streams where they destroyed a much larger proportion of the crops.

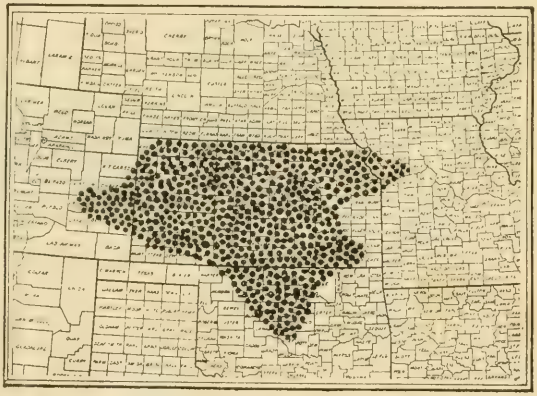

FIG. 1.—Map of Kansas and neighboring States, showing location of grasshopper outbreaks during the years 1911, 1912, and 1913. (Original.)

In recent outbreaks all of the grasshoppers concerned have been native species whose ravages have been limited to crops in the neighborhood of their birthplace, and unless control measures are adopted against them further agricultural development of the semiarid region

will be followed by increased damage. As might be expected, succulent truck crops and sugar beets, in a region that is almost barren of other tender vegetation, are attacked by many insects, and among the first of these are the native grasshoppers.

In 1913 occurred the worst outbreak seen in Kansas for years. (See map, fig. 1.) People were forced to apply control measures on

FIG. 2.—The differential grasshopper (*Melanoplus differentialis*): Adult. Enlarged. (Original.)

a larger scale than ever before. All crops such as sweet corn, onions, and rhubarb suffered severely. Taking the country over, it is likely that every kind of garden and truck crop suffered damage from grasshopper attacks. As a result, progressive growers are eagerly seeking preventive and remedial measures.

DESCRIPTION.

The four species which accomplished most of the injury to Kansas truck crops during 1911, 1912, and 1913 were the differential grasshopper (*Melanoplus differentialis* Thomas), the two-lined grasshopper

FIG. 3.—Two-lined grasshopper (*Melanoplus bivittatus*): Adult. Enlarged. (Original.)

(*M. bivittatus* Say), the lesser migratory grasshopper (*M. atlanis* Riley), and one for which the writer knows no common name, but which, in view of its scientific name, *Acoloplus bruneri* Caudell, we may call "the Bruner grasshopper." The adults of all four species intermingle during July and August.

The differential and the two-lined grasshoppers are the two large species having yellow bodies from 1 inch to 1½ inches long. The head and neck of the differential grasshopper (fig. 2) bear few if any dark markings, the forewings are uniform light olive-green, and the outside of each hind thigh bears a row of black V's that open backward, with a row of black dots just below.

The two-lined grasshopper (fig. 3) receives its name from the two yellow stripes that extend backward, one from each eye, across the

neck and forewings, with a stripe of dark brown between. A black stripe on the hind thigh extends almost its entire length on the outside upper half, and the slender second joint is usually bluish-green.

The lesser migratory grasshopper derives its name from its resemblance in markings and habits to its destructive relative, the Rocky Mountain or migratory grasshopper. Its body is from three-fourths to 1 inch in length, and is yellowish-brown with darker markings. There is a resemblance between this species and the red-legged grasshopper, which is found over about the same territory. The type may be recognized by the dark band on the front two-thirds of the upper half of the neck, a light stripe on each side from the base of the wing to the socket of the hind leg, and three dark bands across the top and down each side of the hind thighs. Through the center of each front wing a light stripe runs lengthwise, widening backward, and containing several squarish dark patches.

FIG. 4.—The Bruner grasshopper (*Acoloplus bruneri*): Adult. Enlarged. (Original.)

The thick-set body of the Bruner grasshopper (fig. 4) is about 1 inch in length and is of a greenish-yellow color. Three bluish-green stripes extend from the head backward across the neck, one on top and one on each side. The front wings are olive green, finely netted with yellow cross veins, and with a wedge-shaped area lengthwise through the center, bearing light and dark patches. Three bluish-green zigzag stripes on the hind thighs extend across the upper surface and down on each side.

EGG LAYING.

Between the time of maturity, which differs for each species, and freezing weather the females deposit their eggs, selecting for this purpose firm soil in a well-drained location. A hole is formed by working the abdomen downward and backward into the soil as far as it will go, and the eggs are deposited therein, one at a time, as the abdomen is slowly withdrawn. (Fig. 5.) A white, frothy liquid, deposited with the eggs, fills the spaces among them and moistens the walls of the hole. As the liquid dries, it hardens, cementing the yellowish-brown eggs and moist soil into a curved, cylindrical capsule. (Figs. 6, 7.)

Abandoned fields, turn rows, the undisturbed strips under fences, along neglected roadsides (see fig. 8), and on banks of irrigating ditches, and buffalo sod along the edges of infested fields are favorable places for egg laying.

DEVELOPMENT.

The eggs hatch about the time of the last spring frosts, when warm weather is assured. The young grasshoppers push upward to the surface and soon begin feeding on the nearest vegetation. At first they are from one-eighth to three-sixteenths of an inch in length and almost white. Exposure to light and air soon develops dark patches

FIG. 5.—Differential grasshopper laying eggs. Enlarged. (Original.)

in the skins, which make them difficult of detection when resting on soil or dead vegetation. Under favorable weather conditions the grasshoppers increase rapidly in size. The old skins stretch, are finally ruptured, and the young insects escape. This is the process known as molting and occurs five times before the grasshoppers are full grown. The newly acquired skins are very elastic for a short period after molting, and during this time there is a further rapid increase in size. The wing pads on the sides of the body above the legs become larger with each molt, the wings being fully developed after the last molt has taken place.

HABITS.

The young grasshoppers are most active on clear, warm days, during which they feed much of the time. At night and during cool days they seek shelter among standing vegetation or under rubbish

FIG. 6.—Egg capsules of the differential grasshopper, enlarged 1½ times. (Original.)

and clods. They travel by jumping and crawling and are exhausted by slight exertion.

The adults of the lesser migratory grasshopper can fly long distances, but never do so except in search of food or to escape unfavorable conditions. The adults of the other three species under consideration have wings that are small in proportion to the size of their

FIG. 7.—Egg capsules of the Bruner grasshopper, 1½ times natural size. 1, dorsal view; 2, lateral view; 3, ventral view; 4, dorsal view of eggs in capsule; 5, lateral view of eggs in capsule. (Original.)

bodies and they can not fly far. Only a lack of food or very unfavorable surroundings will produce a migration to any great distance. Lack of suitable ground in which to deposit eggs may produce short migrations in all species, but it is probable that all of our injurious native species remain within 1 mile of their birthplace.

CLIMATIC CHECKS.

After grasshoppers become established in a locality they will not starve during an ordinary drought. The variety of plants they can use for food enables the young to mature if any vegetation starts in the spring. After maturity the adults can always find enough food to keep them alive until the eggs are laid.

When exposed to the sun on hot days, soft dirt, with hard dry soil below, reaches a temperature above 150° F. Grasshoppers can not deposit eggs in such hot soil and therefore seek shaded ground for egg laying. This sometimes results in eggs being placed in poorly drained or heavy land, while others are placed in soil that becomes

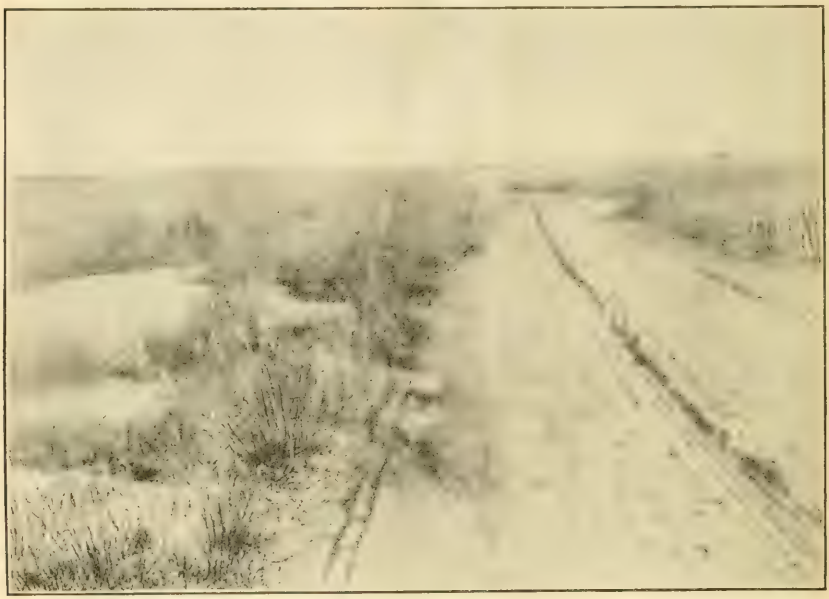

FIG. 8.—A neglected roadside. Russian thistles, sagebrush, and other weeds, interspersed with buffalo sod, form an ideal breeding ground for grasshoppers. (Original.)

overheated later. In either case the vitality of the eggs is materially affected, often to the extent of being destroyed, as was noted during the hot weather of 1913, which was partly responsible for the reduction in the number of grasshoppers hatching the following year.

NATURAL ENEMIES.

ENEMIES OF THE EGGS.

Two of the most effective enemies of grasshopper eggs in Kansas are the larvæ of the bee flies[1] and of blister beetles.[2] (See figs. 9 and 10.) These are white, grublike creatures that burrow into the cap-

[1] Bombyliidæ. [2] Meloidæ.

sules when fresh and feed upon the grasshopper eggs until they attain full growth.

A small wasplike parasite,[1] from one-eighth to three-sixteenths of an inch in length, has been reared from the eggs of the differential grasshopper, the two-lined grasshopper, and others. The female parasites cling to the bodies of female grasshoppers until the latter lay their eggs. As a grasshopper digs the tunnel in which to deposit her eggs the parasites crowd into it along her abdomen, and thrust their eggs singly, one into each grasshopper egg. The developing parasites then feed on the contents of the grasshopper eggs, destroying them.

Small rodents (mice, ground squirrels, and perhaps many others) and moles dig over egg-infested land, especially around the bases of

FIG. 9.—Grasshopper egg capsules and the bee-fly larvæ and coarctate larvæ of blister beetles that were collected along the roadside shown in figure 8; 53 of these parasitic larvæ were found in the grasshopper egg capsules collected in one hour. About natural size. (Original.)

weed stalks, to secure the capsules for food. Skunks share in this work, as indicated by the larger holes, footprints, and other traces. Hogs also eat the eggs and will turn the soil over thoroughly to obtain them.

ENEMIES OF THE YOUNG AND ADULTS.

A red mite, which is reported to have destroyed many of the Rocky Mountain grasshoppers during the seventies, does not kill many of our native species. The writer counted 135 of these mites on a single adult grasshopper which was still very active.

[1] *Scelio monticola* Brues.

Young grasshoppers are frequently stung by female wasps, paralysis follows, and they are then stored to nourish the wasp larvæ. Several dozen helpless young grasshoppers have been dug from a single wasp

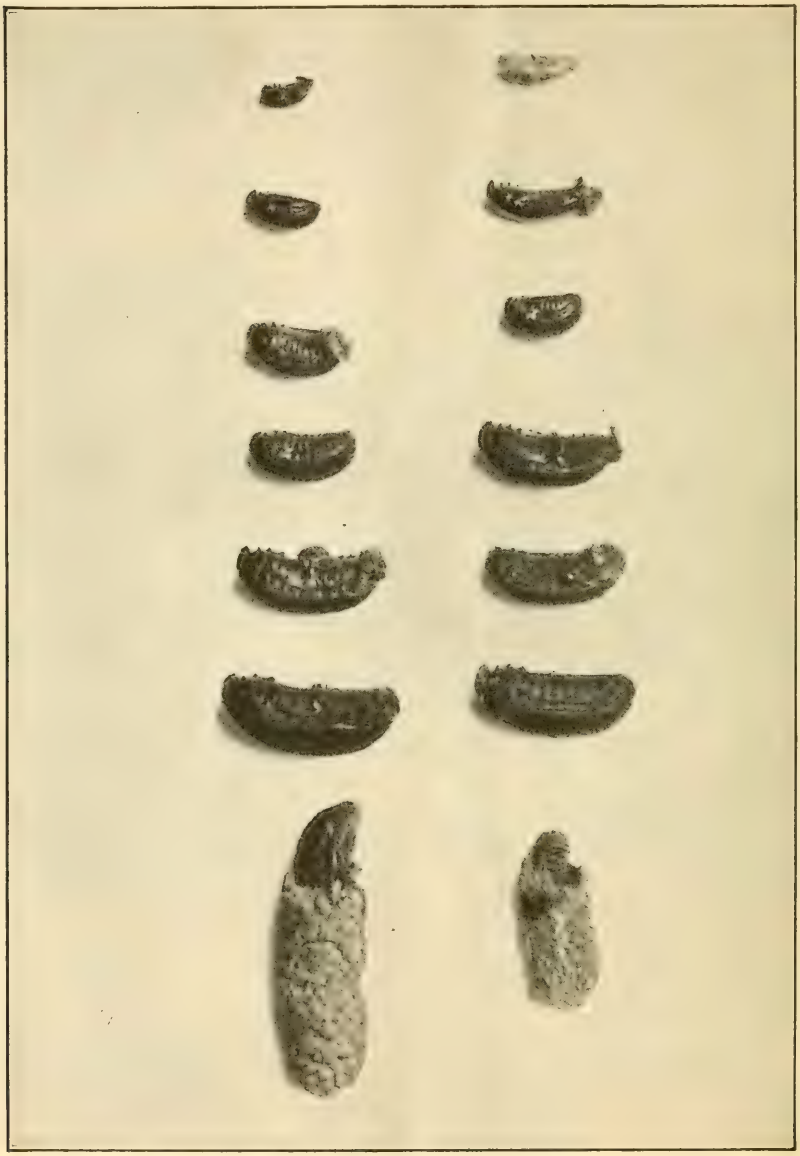

FIG. 10.—Blister beetles: Coarctate larvæ (winter stage) of several species, 1½ times natural size. At bottom are two as found, partly within the grasshopper egg capsules. Most blister-beetle larvæ before transforming burrow some distance from the egg capsules in which they feed. (Original.)

burrow. The larger spiders as well as ground beetles feed on such grasshoppers as they can secure. Parasitic flies deposit their eggs or living young on the grasshoppers and the maggots enter the body

and feed until grown, when they tear their way out, killing the grasshopper. These flies become very abundant in the fall of years of severe grasshopper outbreaks.

Toads, practically all lizards, and some snakes, feed to a considerable extent on grasshoppers. Cats and ground squirrels have been seen to catch and eat those of the larger species. Birds, practically all of which feed upon grasshoppers, destroy large numbers of both young and adults.

In some places chickens, turkeys, and guinea fowl are raised to catch them, constituting one of the most practical means of checking their outbreaks.

The chinch-bug fungus is known to kill large numbers of grasshoppers. In localities of eastern and central Kansas the differential and two-lined grasshoppers were almost wiped out by this disease during the fall of 1911. While the Bruner grasshopper was maturing during June of 1913, many nymphs and adults were killed by it. Reports of grasshoppers dying in western Kansas during the same period indicated a widespread outbreak of the disease. Its presence among the grasshoppers is easily recognized, as the dead insects remain clinging to the tips of weeds and grass, sometimes several in a cluster.

CONTROL MEASURES.

The control measures herein recommended are the most effective that have been tried in Kansas during the years 1911 to 1914, and when carefully applied the value of the crop saved will be several times the cost of application. These measures come under two heads: (1) Those for destroying the grasshopper eggs, and (2) those for destroying the young and adult grasshoppers.

DESTRUCTION OF THE EGGS.

PLOWING.

If egg-infested land requires plowing for the next crop, no other treatment need be given. However, the plowing should be at least 6 inches deep and should be finished as much before April 15 as possible. This covers the eggs so deeply that the young can not get out when they hatch.

HARROWING AND DISKING.

If plowing is unnecessary for the following crop, the eggs can be destroyed with little expense by stirring the ground to a depth of about 2 inches by March 1. This breaks and crushes many capsules and exposes others to the attacks of enemies and disease, as well as to drying and freezing. In clean ground that is soft enough a heavy harrow will stir the soil sufficiently. Three or four sections drawn

by five horses will cover the ground rapidly. In heavy soils, weedy fields, alfalfa, or land in which patches of sod occur, the disk harrow is required; but in alfalfa it should not be set deep enough to cut off the crowns of the plants. The land should be left rough to expose as many eggs as possible, and after hard freezing weather it should be harrowed to expose any eggs that may have been covered before.

It is difficult to destroy eggs in buffalo sod. Breaking is not usually done deep enough to keep the young from escaping or the slices of sod are not left close enough together. No other cultivation can be given sod land. Hogs will root out and eat some of the eggs, but their use is not practicable for a large area. The egg-infested sod should be left until the young have hatched, when they can be killed by burning or by one of the other methods recommended for their destruction. Scattered clumps of egg-infested grass in turn rows, under fences, in abandoned fields, or along roadsides should be chopped out before March 1 with a heavy hoe or a spade.

DESTRUCTION OF THE YOUNG AND ADULTS.

POISONED BRAN MASH.

During 1911, 1912, and 1913 a bait of poisoned bran mash was used very successfully in Kansas to check outbreaks of native grasshoppers. In 1913 alone more than 1,000 tons were provided at public expense in about 20 counties of western Kansas and spread on grasshopper-infested land. This bait has been successfully used since then against grasshoppers in New York, Canada, California, and Florida.

The proportion and quantities of ingredients that can be most easily handled are given in the following formula:[1]

Bran	pounds	25
Paris green or white arsenic	do	1
Oranges or lemons		6
Cheap sirup or molasses	quarts	2
Water	gallons	[2] 3

Mix the dry bran and poison in a washtub. Add the sirup and the juice and finely chopped pulp and peel of the fruit to the water. Then pour the water over the mixture of bran and poison, stirring to dampen it thoroughly and add as much more water as the bait will

[1] The addition of oranges or lemons to the poisoned bran mash was made as a result of the author's work with the Kansas Agricultural Experiment Station during 1911. The increased effectiveness of the bait when applied broadcast, with the accompanying elimination of the danger to poultry and live stock, was also established at this time.

[2] Three gallons of water may be sufficient for 25 pounds of bran where it is to be used in a humid climate; but in the semiarid region at least 4 gallons must be used, otherwise the bait dries too rapidly to give the maximum efficiency. When it is scattered the bait should carry all of the moisture it can without losing any. Whether or not 3 gallons of water is sufficient for 25 pounds can be readily determined by adding that much water to 25 pounds of bran. In Kansas there would be no difficulty in adding 4 gallons, if half a gallon of sirup is used. The writer would add 4½ gallons of water. It is difficult to believe that bran will hold so much water until one has seen the fact demonstrated.

hold, usually about 1 gallon. While fresh, the wet fruity mash is very attractive to grasshoppers; but when dry or stale it is not eaten. The bait is applied by sowing it broadcast on the infested land late in the evening or early in the morning. Very early morning is to be preferred, as the grasshoppers are then just beginning to feed, and they have a longer time to eat before it dries than if it were applied at any other time. The bait should not be spread just before a shower, as rain washes the poison from the bran flakes, leaving them harmless. Little of the bait is eaten after the first day, even in damp weather. Therefore several applications may be necessary to check damage by grasshoppers in badly infested fields, or to keep injurious numbers from drifting into a field.

The amount of bait prepared by using the quantities of ingredients given in the formula will sow 6 acres of heavily infested land. This makes the cost of one application about 25 cents per acre. Ordinarily this amount should be spread over about 12 acres, which reduces the cost to 15 cents per acre or less. When the bait is to be applied a small quantity of known weight should be mixed and sown that it may be ascertained how very little is required when only 2 to 4 pounds of bran are to be used to the acre.

Neither domestic animals nor birds can secure enough of the poisoned bait to kill them, if it is scattered evenly as directed. However, a few cautions regarding its use may not be out of place. It should never be placed in heaps or scattered thickly. The poison and mixed bait should be kept out of the reach of children and of domestic animals. Utensils used in handling the bait should be thoroughly scrubbed before being used for any other purpose. The dry, powdery poisons should not be exposed to the wind or handled roughly or carelessly. The bran and poison should be mixed with a spade or wooden paddle. If the hands are used for this purpose enough poison may be absorbed by the back of the hands and the forearms to cause severe intestinal cramps and diarrhea. However, the writer has never known poisoning to occur simply from sowing the wet bait barehanded.

THE HOPPERDOZER.

The hopperdozer is an old device for using kerosene, crude oil, or tar in catching grasshoppers and was developed during the migratory grasshopper years of 1874–1876. It consists of shallow sheet-iron pans, containing the oil or tar, which are mounted on low wheels or sled runners. An upright screen at the back catches the "hoppers" as the machine is drawn forward.

The hopperdozer is simple in construction. (See fig. 11.) The pan is made by turning up 6 inches of the edge of a sheet of galvanized iron, 8 feet long and 30 inches wide. Two inches of the edge is then turned down over the pan to prevent slopping, and two partitions

soldered across it to keep the liquid from running to one end and spilling when operated on sloping ground. The sled floor is 18½ inches from front to rear, being made of one board 1 by 6 inches and one 1 by 12 inches with a narrow space between. It can be either 8 or 15 feet long to hold either one or two pans. A strip 1 by 4 inches on edge around it keeps the pans from sliding off. The runners are pieces of 2 by 4 lumber 4 feet long, laid flat and rounded at the front ends. They should extend about equal distances in front of and behind the floor. An 8-foot sled needs two runners and a 15-foot sled needs three. The screen behind the pans should be of oilcloth, smooth side forward, nailed to uprights at the back of the sled. The hitch is made by nailing a 2 by 4 across the runners in front of the pan and letting the ends project 2 or 3 feet at each side. Each end is braced by a board extending to the end of the runner behind the pan.

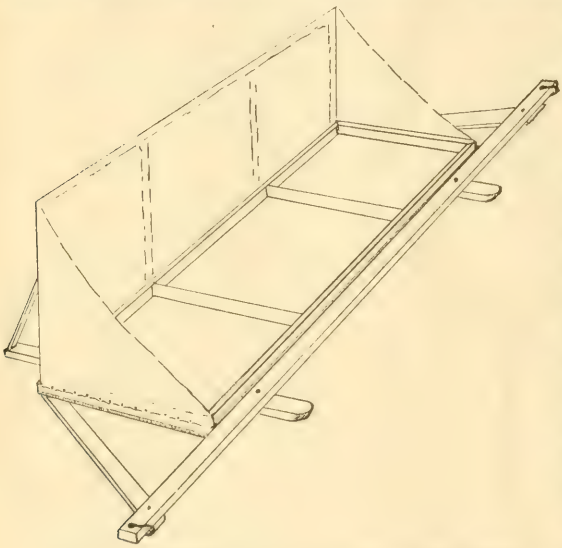

FIG. 11.—A successful type of horse-drawn hopperdozer. (Original.)

For use, the compartments of the pan should be half filled with water and enough kerosene or crude oil should be added to form a film. If tar is used, a thin layer is spread in the bottoms of the otherwise empty pans. As the hopperdozer is drawn forward the grasshoppers jump up and fall into the pan, or strike against the screen at the back and drop in. Contact with a little tar or a wetting with the oil kills them, even though they jump out afterwards. The dead that collect must be shoveled out at intervals and the tar or oil and water replaced.

When large fields of fairly level land are to be treated with the hopperdozer, two or three pans are often set on the teeth of a sweep rake. This makes the work easy for the team, but on rough ground the liquid slops badly. In such cases two sleds holding two pans each, having for runners pieces of 2 by 4 set on edge, should be placed end to end. The two adjacent runners should be loosely bolted together through a 2 by 4, which is placed on edge between them. The middle 2 by 4 should project behind from 4 to 5 feet, and from its end a strong wire should be stretched to the outer back corner of each sled.

This wire and the 2 by 4 brace the "double" hopperdozer so that it can be drawn by two teams, one hitched at each end. Being flexible in the middle, it can be used on very uneven ground that will sometimes throw the ends much higher or much lower than the middle. Of course the screens at the back must be arranged so as not to interfere. The wide sweep (30 feet) of this hopperdozer enables the ground to be covered rapidly, which is very important during severe outbreaks, and the teams are so far apart that they do not drive many grasshoppers before them.

BURNING.

Sometimes many grasshoppers hatch in dead vegetation where they can be destroyed by burning. This frequently occurs on buffalo sod, in neglected fields, or along roadsides. Burning is then the cheapest and most effective means of killing them. If there is not enough dead vegetation to carry the fire, some old hay or straw scattered through the infested area will help to produce enough heat to kill the insects. Opportunities for destroying native grasshoppers by burning should not be neglected. A sufficient number can hatch in one-fourth of an acre of sod to ruin a neighboring garden, yet half a day's work and a load of straw or old hay would burn them all.

UTILIZATION OF POULTRY.

Where grasshoppers are an annual pest, farmers can protect their crops and make a profit on the insects by raising poultry to catch them. The value of chickens and turkeys in destroying grasshoppers is proved anew by each succeeding outbreak, yet comparatively few farmers utilize them as a means of control.

During the late nineties many turkeys were raised to catch grasshoppers on the valley lands along the Solomon River in northern Kansas. Children herded the flocks where grasshoppers were the most destructive, and so successful was this method of saving crops that more farmers adopted it every year until that series of grasshopper outbreaks ended.

Near Scott City, Kans., during 1911, the second crop of alfalfa on a 100-acre field was badly damaged. The owner secured about 100 turkeys and turned them into the field. When the writer visited the place during the third week of August a few of the lesser migratory grasshoppers that could escape capture by flight were the only ones present. The alfalfa was uninjured and was then about 18 inches high.

In June, 1912, the writer constructed a portable henhouse for about 36 grown chickens. It was located on or along the edges of grasshopper-infested fields, being moved to a new place when no "hoppers" were left near by. This flock was fed only a little grain, and while not quite so many eggs were obtained from the hens in comparison with

hens handled in the ordinary way, many grasshoppers were caught and the hens acquired such a taste for them that upon being returned to the barnyard they ranged far and near in search of insects.

The Kansas Experiment Station at Garden City bought several hundred chicks in an effort to save their crops during the severe grasshopper outbreak of 1913. A wooden framework, on low trucks, constructed of 2 by 4 material, was built and covered outside with poultry netting and inside with canvas. This portable chicken house was easily hauled from place to place, and was considered the most effective means yet adopted in destroying grasshoppers.

During 1913, near Garden City, rhubarb was attacked by grasshoppers that were rapidly stripping the leaves. The gardener placed in separate coops near it three hens with a total of about 40 active chicks. A few days later the rhubarb was free from grasshoppers and the chicks were catching others in adjacent parts of the garden.

UTILIZATION OF HOGS.

Hogs of all ages become very fond of grasshoppers whenever they are allowed the run of infested land. They are reported as efficient destroyers of both grasshoppers and their eggs. A small lot in a field which had been left for alfalfa seed was fenced as pasture for a few hogs. Grasshoppers damaged the entire field except in the hog lot, where a good crop of seed was set.

PROTECTING SUGAR BEETS, TRUCK CROPS, AND GARDENS.

Land prepared for sugar beets is usually plowed more than 10 inches deep. This is often done late in the fall or early in the winter. Throughout the summer the growing beets require frequent cultivation, which drives away grasshoppers that wish to lay eggs. Digging the beets in the fall stirs the surface soil so much that any egg capsules in it are injured or exposed. Only along the edges of fields and, in irrigated districts, on the banks of ditches is there any danger of eggs being left undisturbed.

Many truck and garden crops are grown on land that is plowed deep late in the fall or during the winter. They also require frequent summer cultivation and, with some, the ground is stirred by harvesting. Consequently there is not much danger of such fields being used by grasshoppers for egg-laying purposes. From the facts mentioned it is evident that grasshopper damage to sugar beets, truck crops, and gardens is the result of invasion from adjoining infested land.

If many grasshoppers are present during August and September a search should be made to locate their eggs. Clumps of grass should be chopped out and torn to pieces. Here and there in suspected buffalo sod a square foot of ground should be examined to a depth of about 2 inches for eggs. Where the soil is more easily worked the

spaces examined may be a yard square. An average over a large area of one capsule of eggs per square yard means a severe outbreak the next year. From each capsule that remains sound 25 to 150 young may hatch. Spots well suited to egg laying are often more heavily infested than this.

When the eggs have been located, measures for their destruction can be applied. These should be delayed until the parent grasshoppers die, in order that no more eggs may be deposited. If the egg-infested land requires plowing for the next year's crop, no other treatment need be given. When plowing is not required, the harrow or disk may be used. Suitable treatment should be given the edges of fields, ditch banks, turn rows, abandoned fields, roadsides, or any other places where eggs are to be found. Scattering clumps of egg-infested grasses should be uprooted, even when the surrounding land receives no treatment.

Where the eggs can not be destroyed, the infested area should be watched and the young killed when they hatch in the spring. On waste land, pastures, and sod that can be burned over, fire is the best means of destroying them. If it can not be used, and young chicks or turkeys are available, these should be put into a portable henhouse and located between the infested land and any field into which the young grasshoppers are likely to go. The flock can be moved to a fresh location as the land near by is cleared of "hoppers." In this way the grasshoppers can be worked back from the field and the danger of invasion lessened. If the infested area is large, the poultry may be brought almost to maturity with a comparatively small outlay for feed and with a constantly decreasing number of grasshoppers that will be left to deposit eggs in the fall.

There should be no delay when grasshoppers hatch in great numbers over a large area, for the expense and difficulty of combating them increase rapidly as they grow larger. If no other means of control are ready for use at once, the poisoned bait or the hopperdozer must be relied upon. The time available for the work, the cost of application, and perhaps other factors must be considered in choosing between the two methods. The bait is cheaper, less time is required to treat land with it than with the hopperdozer, and it can be prepared in any quantity. With a 2-gallon pail of bait one can sow in fields and in locations the character of which makes the use of the hopperdozer impossible. Consequently this method is most frequently chosen.

If grasshoppers have already invaded a beet field or garden, the bait must be applied all over it. Several applications at intervals of two days are sometimes necessary to check the injury. The infested land from which the grasshoppers are coming should also be treated vigorously with the most suitable method. Around the

edges of fields, and in fields where the crop permits it, a tubful of bait can be placed on a sled or in a wagon, and the driver can sow from it, thus getting over the ground rapidly. The "hoppers" in fields of low-growing crops can be caught with a hopperdozer if time permits and teams are available. But in fields of tall-growing crops, where many grasshoppers are on the plants at all times, a modified bait should be used. It is prepared by using three or four times the usual quantity of sirup and correspondingly less water. It should be applied by throwing small quantities among the tops of the plants so that it will stick to the leaves or blades. There it will attract the grasshoppers immediately. The poison is washed off by rains or shaken off by handling, so there is no danger to animals that feed on crops treated in this manner. This sticky bait should also be thrown among the tops of bushes or trees in which the insects feed.

ESSENTIALS FOR SUCCESSFUL WORK.

The most frequent causes of failure to check grasshopper outbreaks when methods of control are applied are (1) lack of cooperation among the landowners of the infested community and (2) misdirected or careless application of recommended control measures. The former, however, is more often the cause.

In many localities part of the land is held by speculators, who often permit it to lie idle for several years in succession. If such land is in sod, grasshoppers use only the outskirts for depositing eggs, but if it has been broken and then neglected, a sufficiently heavy growth of weeds is often produced to make it a breeding place for large numbers of grasshoppers. Where there is much of such land in a community the grasshoppers must be destroyed on it, as well as on the edges of cultivated fields, along roadsides, or on pasture land; otherwise it becomes the center from which "hoppers" scatter to the crops on adjoining fields.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

OUTDOOR WINTERING OF BEES.

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and

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INTRODUCTION.

The beekeepers of the United States lose at least one-tenth of their colonies of bees every winter. This is a minimum loss, which is frequently increased to one-half and sometimes more in certain sections. This decrease is largely due to carelessness or to lack of knowledge, and it is entirely practical to reduce it to less than 1 per cent, the small loss covering various accidents which can not be foreseen. An industry which can survive in the face of such a decrease must have great possibilities for commercial advancement when the loss is properly reduced.

An important reason for the unnecessary death of colonies in winter is the belief of many beekeepers that, since unprotected colonies often live over winter, no protection is needed. When, for example, heavy insulation of bees is advocated at a beekeepers' convention, some beekeeper usually replies that he has never protected his colonies and never loses any. His reported success is often unintentionally exaggerated, and he indicates by such statements that he may not know what constitutes moderately successful wintering. Although probably nothing on a farm gives a better return on the investment than do bees if well cared for, the majority of beekeepers neglect them. It need scarcely be stated that the best beekeepers do not follow such a parsimonious and unwise policy.

It is usually believed that winter loss is confined to the northern portions of the country, but this is far from true. The beekeepers of the South lose many colonies during this season, and, peculiarly

NOTE.—This bulletin deals with the care of bees in winter when wintered outside and is of interest to beekeepers in all parts of the United States.

enough, the decrease in all parts of the United States is due to the same causes in varying degree.

For the past three winters the authors[1] have made a study of the activity of bees during the winter and of the effects of various environmental factors on the colony. This bulletin does not include the results of this work, but gives the methods of outside wintering which have proved best in commercial apiaries, all the statements here made having been substantiated by the results of the more detailed studies which are to be reported in other form. There are many factors which require still more study and the doubtful points are not here discussed. It seems best not to include a discussion of the wintering of bees in cellars, concerning which there are many more points in dispute which can be settled only by detailed scientific studies. This omission should not be interpreted as indicating that the authors condemn cellar wintering; in fact, they are inclined to believe that when properly worked out this method will be found superior in northern localities.

Beekeepers usually report the results of wintering by giving the percentage of colonies in which all the bees die, just as was done in the first paragraph of this bulletin. This is a convenient method but is misleading. If every individual bee that goes into winter quarters remained alive in the spring with no loss of vitality, we should have perfect wintering, but such success is impossible. If out of 100 colonies only 2 die and the remainder are only half as strong in numbers as they were in the fall, most beekeepers would consider this rather good wintering, while in fact it is poor. The criterion of success is to save the greatest possible number of individual bees and to have them capable of prolonged activity in the spring. Beekeepers sorely need a new point of view as to success with this vital problem.

Frequently in beekeeping literature mention is made of the "winter sleep" of bees. Bees can not hibernate as do most insects. While the bees on the outside of the winter cluster are usually quiet, there is incessant movement in the center during cold weather; in fact, the colder the surrounding air, the greater the activity of the colony after a cluster is formed. The phrase "winter sleep" is therefore erroneous and should be dropped from the literature, as it misleads beekeepers.

CAUSES OF WINTER LOSS.

The causes of the death of individual bees or of a colony of bees in winter, barring unusual accidents, are only two in number: (1)

[1] For a preliminary report of this work see Phillips and Demuth, 1914. The temperature of the honeybee cluster in winter, Bul. 93, U. S. Dept. Agr., 16 p.

Inadequate stores and (2) excessive heat production. The numerous factors usually given in the literature on the subject as entirely distinct fall into these two classes, except for some that are usually given which the authors do not believe to be operative.

EXCESSIVE HEAT-GENERATION.

It was first shown by the authors in the bulletin to which reference has been made that at hive temperatures between about 57° and 69° F. a normal broodless colony of bees does not form a cluster, but the bees remain inactive on the combs. When the temperature of the air immediately surrounding the bees (not the temperature of the air outside the hive) falls to 57° F. or lower, they form a cluster and those in the center begin to generate heat by muscular activity, while those in the outer portion serve as insulators by crowding close together, usually with their heads toward the center of the cluster. The innermost portion rapidly acquires a temperature considerably higher than that of the air about the bees before clustering was necessary, often going to 90° F. in normal colonies and higher in abnormal ones. The number of bees engaged in heat production increases as the outer temperature falls and the insulating zone is consequently decreased in thickness but becomes more compact. The entire cluster becomes smaller as the outer temperature falls.

If bees can be kept in an environment such that the temperature of the air immediately surrounding them is 57° F. or slightly above, they are saved much unnecessary and unprofitable labor. To the theoretical objection that bees need exercise, it is necessary only to state that the authors have so wintered bees in a cellar as well as outdoors with wonderfully successful results. If bees are kept in a cellar under the best conditions the results are excellent, but it is not proposed to discuss this more complicated phase of the subject here. If wintered outside in a packing case with abundant insulation, any heat generated escapes slowly and the temperature of the air in the hive rarely falls below 55° F. If inadequately protected, the temperature of the hive can not be kept so high and the bees must generate much more heat. In single-walled hives it is common for the temperature of the air around the cluster to fall to freezing or lower, in which event the bees generate an excessive amount of heat and perhaps die when they are no longer capable of the necessary muscular activity. The necessity of packing is thus made clear, and in any locality in which the outer temperature often falls to 40° F. or below it is desirable to protect bees to conserve their vitality. If the temperature should fall to 40° F. only a few times during the winter, this would not be serious enough to make insula-

tion necessary. It is obvious, however, that winter protection is beneficial throughout practically the entire United States.

Necessity of having young bees.—Bees may be compared with minute dry batteries, in so far as their vital energy is concerned. They emerge as adult bees with a certain amount of vital energy, and when this is exhausted they die, not having power to recover lost vitality as human beings have. To withstand the hardships of winter under usual conditions, a colony must have many young bees, capable of prolonged muscular work. Obviously the better the wintering conditions, the less necessary it becomes to provide young bees, but even with the most perfect wintering it is desirable that there be plenty of young bees in the fall, so that they will be available for extensive brood-rearing in the spring. This calls for prolonged brood-rearing in late summer. Old bees, which have been worn out earlier and are ready to die, soon succumb from the work of heat-generation.

Danger of weak colonies.—In a strong colony many bees in the center of the cluster may be engaged in heat-generation, and there will still remain many bees to serve as insulators. A weak colony, on the other hand, has less reserves for insulation, and, since heat is rapidly lost, the bees on the inside must generate excessive heat in order that the outermost bees may always be at a temperature of over 50° F. Since the surface of a spherical cluster is proportionate to the square of the diameter, while the volume is proportionate to the cube of the diameter, it follows that a large colony cluster has a relatively smaller surface for radiation of heat than does a small one. Below about 50° F. individual bees become numb, and so long as the cluster remains active the authors have never found normal bees at a temperature lower than the critical temperature, 57° F. In a small colony the inner temperature is often many degrees warmer than that of a neighboring strong colony, which doubtless explains the prolonged brood-rearing of weak colonies in the fall. Most colonies which die of excessive heat-generation are rushed to their doom by the temperature being high enough to start brood-rearing, which is perhaps one of the most unfortunate circumstances which a colony can experience in winter. By all means a colony should be so protected that brood-rearing will not be begun until frequent flights are possible.

Since weak colonies so frequently succumb in winter, it is obvious that a too rapid increase in the number of colonies in summer is unwise. Beekeepers have learned that swarming is to be avoided because of the resulting reduction in the honey crop, and the loss in winter is additional argument against allowing the bees to exercise this instinct freely. It is a common saying among beekeepers that a rapid increase is usually followed by a rapid decrease. It is impossible to

get too strong a colony for winter, the error always being in the opposite direction.

Effects of accumulation of feces.—It was first shown by the authors that heat-generation causes increased consumption of stores; this in turn causes an accumulation of feces within the bees, which is more rapid if the stores contain a high percentage of indigestible materials, and the presence of feces causes increased activity, often resulting in death from excessive heat-generation. Beekeepers call this condition dysentery if the accumulation is so excessive that the bees are unable to retain the feces. Dysentery causes the death of bees in winter, so far as has been seen, solely by undue activity and excessive heat-production. This detrimental effect is reduced by good stores, but obviously the proper method is to prevent an unnecessary accumulation of feces by preventing a heavy consumption of stores, chiefly by providing a sufficiently high surrounding temperature. Honey-dew honey is especially injurious because of the rapidity with which feces accumulate.

In mild climates, in which there are frequent days when bees can fly and rid themselves of feces, the injurious effects of poor stores are less noticeable, because the feces do not accumulate sufficiently to cause abnormal activity. The accumulation of feces is to be considered as an irritant, causing responses similar to disturbance by jarring or exposure to light.

Influence of the queen.—In discussions of wintering it is usually stated that to winter well a colony must have a good queen. Obviously a good queen will better prepare a colony for winter by providing a strong colony of young bees than will a poor one, while a colony that is queenless in late summer and fall has little chance of living until spring. A good queen will also increase brood-rearing rapidly in the spring, if the colony has good stores and has been properly protected during the winter. Aside from the important influence on the population of the colony, the queen probably plays no part in wintering.

Spring-dwindling.—If the individual bees of a colony are reduced in vitality by excessive heat-production, they may live until spring, but are unable to do the heavy work then needed to bring the colony back to full strength. The adult bees die more rapidly than they are replaced by emerging bees, and the population decreases. This condition, which can be produced experimentally, has long been known among beekeepers as "spring-dwindling." If this condition is observed, the bees may perhaps be slightly relieved of further unnecessary work by packing to conserve heat and by giving abundant stores, but the proper treatment is to prevent the condition by proper care in the preceding fall and winter. The term "spring-dwindling" should not be applied to death of bees from other causes.

LACK OF STORES.

A common cause of the death of colonies in winter is starvation, which is more certainly due to carelessness on the part of the bee-keeper than is unnecessary heat-production. The greater the necessity for heat-production, the more necessary it becomes for every colony to have an abundance of stores of good quality. The amount required varies with the length of the winter, and also with the amount of heat which is generated. It is, of course, necessary also to provide or leave stores enough for brood-rearing in late winter or spring, before sufficient stores come to the hive from natural sources.

COMPARISON OF THE COLONY WITH A FURNACE.

Let us assume that we have a furnace for heating a building so constructed that ashes may be removed only when the temperature of the outer air is warm. If the house has thin walls and many openings, the furnace can not maintain a high temperature in extreme cold weather, the amount of fuel consumed is increased, the ashes accumulate rapidly and clog the furnace, and in a desperate effort to raise the house temperature we should probably burn out the furnace. On the other hand, if the house is well built and heavily insulated, a low fire will suffice, and as a result there will be a minimum amount of ashes. The better the fuel, the less the amount of ashes in either case.

It is permissible to compare a colony of bees as a unit of heat-production with this furnace. If the bees are in a single-walled hive in a cold climate, the colony must generate a great amount of heat, must consume much more honey, and feces will accumulate rapidly. As the bees are unable to discharge their feces until the temperature of the outer air is high enough for flight, the "furnace" is clogged. The bees are "burned out" by the excessive heat-production, and, even worse than in the case of the furnace, the irritation resulting from the presence of feces causes still more heat-production. On the other hand, if abundantly insulated, the heat generated is conserved, the consumption of stores and amount of feces are reduced, and the bees can readily retain the feces until a flight day, in any place in which bees can be kept. The better the stores the less the amount of feces in either case.

We should not expect much of a furnace in an open shed, and we have no more right to expect good results from a colony wintered in a thin-walled hive in a cold climate, or even in a better hive placed in a windy location.

CONSERVATION OF HEAT AND REDUCTION OF EXPENDITURE OF ENERGY.

In outside wintering the heat produced by the bees is conserved by the insulation of the cluster itself and also by the insulation of the hive and packing. In the cellar there is less insulation near the cluster, but the cellar itself replaces the packing, and is in reality simply an insulation. The insulation of the individual hive, of several hives packed together, or of bees in a cellar serves solely to reduce the loss of heat generated by the bees.

The amount of packing that should be used obviously varies with the climate and it is impossible to make definite general statements in a bulletin intended for all parts of the United States. There is one general statement which can be made with safety: The majority of beekeepers do not give sufficient insulation and no beekeeper ever gave a colony too much. For example, in the relatively mild climate of Washington, most beekeepers winter their bees in single-walled hives. The authors have used a large packing case holding four hives, two facing east and two west, close together. This case was constructed so as to hold 3 inches of packing below, 5 inches on the ends, 6 inches on the sides, and 8 to 12 inches on top. Colonies wintered in such a case in Philadelphia in 1913–14, and in the apiary of the Bureau of Entomology at Drummond, Md., near Washington, in 1914–15, were in much better condition than colonies left unprotected, and cases of this general type are being constructed for the entire apiary at Drummond, except for such colonies as are used in other wintering experiments. The dimensions here stated should by no means be accepted as best for other localities, especially those farther north, where the protection should be heavier, but in this particular packing case the temperature of the air within the hive but outside the cluster usually stood at about 55° to 57° F., except for a reduction in temperature under one condition to be discussed on the next page. The aim of the beekeeper should be to keep the air about the bees at about 57° F., at which temperature there is no condensation of moisture within the hive, even on the inside of the cover, where it first appears. It might be inferred that if double the amount of packing had been used the temperature of the air about the bees would have been too high. This is not the case, for bees cease heat-generation when the temperature reaches 57° F., (or even sooner when the surrounding temperature is rising[1]), and the temperature will not exceed 57° F. unless that of the outer air remains higher than that for a considerable period.

Bees well protected and with good stores do not fly from the hive because of the warmth within when the outer air is too cold for them

[1] See Department Bulletin No. 93.

to do so safely. If bees fly at low temperatures (45° to 50° F.), it is an indication that they need a flight because of an accumulation of feces from poor wintering, and does not at all indicate too high an inside temperature because of too much packing. In conclusion, the beekeeper can not apply too much insulating material to a hive.

It has been found that, even with abundant insulation, the temperature within the hive and outside the cluster is greatly reduced if the packing case is exposed to wind. During the winter 1914–15 a record was kept of wind velocity directly over a heavily packed case (with entrances ⅜ inch by 8 inches), and it was found that a wind with a velocity of 20 miles per hour directly on the case reduces the temperature within the hives practically to that observed in an unprotected hive. The beneficial effects of the insulation were therefore nullified, and the proper temperature within the hive was not regained for several days unless the outer temperature rose considerably. Beekeepers have long emphasized the importance of protection from wind, but the results observed were much more pronounced than was anticipated or than has ever been suspected by practical beekeepers. The ideal toward which the beekeeper should work is to keep his colonies during cold weather absolutely protected from wind, for here again the protection can not be too great. It is entirely erroneous to assume, as some have done, that such protection is not essential in well-packed hives.

There are several types of hives on the market in which the insulation is built in, to be retained throughout the year. There is no objection to the packing in the summer, except that such hives are not convenient for moving and in some other manipulations. Insulation in commercial double-walled hives is by means of air spaces or insulation, such as sawdust, chaff, broken cork, or shavings. These hives are better for outside wintering than single-walled hives in any part of the United States, but they do not provide adequate insulation at temperatures below about 40° F. Such hives must, of course, be protected from wind, or they are for the time being no better than single-walled hives.

Types of insulation.—Various materials are used for insulation. Beside those named above, paper, dry leaves, and many other substances are in use. Most of the common insulating materials depend on small confined dead-air spaces for their insulating value, and, in general, the more finely divided the air spaces the more efficient the material. Sawdust is usually condemned, because if moisture escapes from the hive into the packing it is retained and the insulating value is reduced. However, if a colony is sufficiently packed, moisture does not condense, except possibly at extremely low external temperatures, and this objection to sawdust is removed. From observa-

tions so far made, it appears that the beekeeper may use the materials most easily obtained. If dry leaves are used, they should be packed tight, but sawdust should simply be poured in place without being packed tight.

The entrance.—The weak place in hive insulation is the entrance. An opening 8 inches wide and ⅜ inch high is abundant, it usually being constructed as a tunnel through the packing. In cold weather this might be still further reduced. The opening should be shielded from the wind, to prevent a rapid loss of heat, for if the wind blows against the entrance the heat stored up in the packing is lost both to the outside and the inside. The only reason for an entrance as large as the size mentioned above is the danger that dead bees will drop from the combs and block a smaller entrance. Since the number of dead bees is greatly reduced in well-insulated hives this is less important, and, furthermore, if the air within the hive is warmed to 57° F. the dead bees will be pushed outside, even in freezing weather.

Methods of packing.—The exact method of packing is not especially important, provided enough insulation is given on all sides. Colonies may be packed singly in any sort of box, or they may be packed in groups of four, as previously described (p. 7). Some beekeepers arrange colonies in long rows and apply insulation to the whole row. The placing of several hives in contact has the advantage that the colonies insulate one another. If arranged in groups of four, two facing east and two west, they may be left on the same stand throughout the year and are readily manipulated during summer. If in long rows close together, summer manipulations are impeded, unless the hives are moved after the insulation is removed. Placing colonies in long rows is therefore not advisable. Whatever type of outer case is used, it should be tight, to prevent rain and snow from wetting the insulating material.

A rather common practice is to pack the hive at the sides, top, and rear, but to leave the front unprotected and faced to the south, the object being to utilize the heat of the sun to warm up the interior of the hive and reduce the work of the bees. Any place through which external heat may readily reach the interior of the hive is also efficient as an avenue through which heat may be lost when the sun is not shining. Since the sun shines less than half the time in winter, making no allowance for cloudy days, the weakness of the argument for this practice is obvious. A similar practice is to paint the packing cases a dark color to absorb the sun's heat. Considerably more detailed work is needed to determine to what extent this source of heat is of value to the colony.

Time for packing.—At the time of the first killing frost the beekeeper should promptly remove supers, if any are on his hives. If

the bees are not adequately supplied with good stores for winter these should now be given immediately, and, when the feeding is finished, the winter insulation should be applied at once. At this time bees are the quietest of any period of the year. The disturbance incident to putting on the insulation does not do them any harm. After this the beekeeper should have no occasion to open the hive until spring. An outer temperature above 60° F. is desirable at the time of packing, especially if no brood is present. Any day when bees are flying is suitable.

If packing is delayed until late it may do far more damage than to leave the bees unpacked. A colony of bees that is generating heat in response to low temperature is considerably disturbed by the manipulations during packing and the temperature of the inside of the cluster is promptly raised. Frequently, if bees are packed too late (when it is too cold outside), the cluster temperature is raised to brood-rearing temperature, the queen begins to lay eggs, and brood-rearing is usually then continued through the winter, unless it results in the death of the colony, as is often the case. Many beekeepers pack their colonies in December with most harmful results. There is probably no place in the United States where packing is needed in which it is safe to wait later than Thanksgiving Day. Since more beekeepers make mistakes here than in any other phase of outside wintering, this should be emphasized most strongly. The authors have succeeded on several occasions in starting brood-rearing in December by manipulation, both in colonies wintered outside and in removing bees to a cellar, and it is certain that such winter brood-rearing is highly injurious to the colony.

Time for unpacking.—If a colony has a good queen and plenty of stores and is well packed, the beekeeper rarely has any reason for opening the hive until spring is well advanced. If he is not sure of the condition of the colony, he may wish to examine it earlier, but this first examination should be brief and the packing may be partially removed and replaced afterwards. If there are any queenless colonies or any colonies short of stores, these defects should, of course, be promptly corrected, after which the colony should remain undisturbed until, as the season advances, frequent manipulations are necessary. It is often best to leave the insulation on until the colonies need more room, which will probably be as late as May 15 in the North. Colonies which have wintered poorly need their insulation longest, while colonies that have been well insulated, either in a cellar or outside, can, if necessary, stand considerable exposure without much damage, although the work of heat-generation thereby reduces the energy available for building up the colony rapidly.

The time for removing packing may be still further delayed by wintering a colony outside in two-hive bodies, the upper one being

well supplied with honey. Since there is more space to keep warm, such a hive should be more thoroughly insulated. If this plan is followed, the beekeeper is sure that sufficient stores are available and he can probably locate any queenless colonies by a brief external examination. Since wintering in two-hive bodies has not been practiced extensively, it should be tried with caution, but reports of this method should be available from all parts of the country and beekeepers are urged to try it on an experimental scale. The plan has much to commend it.

Providing a windbreak.—It is well established that a windbreak of evergreens is superior to a solid windbreak such as a house or solid fence. The beekeeper can readily determine whether his bees are located in a place where the wind rarely or never blows more than 5 miles an hour in winter. If the apiary is not so located, it should be moved during the summer to a place in the woods, in a gully, or in some other sheltered place. Bees should never be moved in winter. If it is not practicable to move the apiary, a high fence, perhaps 8 feet high, should be constructed on the exposed sides. The more compact the apiary, the easier it is to construct a windbreak, which is an argument for placing colonies in groups of four. Evergreens are slow growing, and a high fence may be used until the permanent windbreak is sufficient. If the apiary is practically surrounded by buildings, this may be adequate protection, but such a location is usually not the most convenient for the apiary. A southern exposure is usually recommended as best for winter, for it is claimed that the heat of the sun is beneficial. Since the sun shines only a small fraction of the time in winter in most localities, especially in the East, where there is much cloudy weather, this feature should not be unduly emphasized.

PROVIDING ADEQUATE WINTER STORES.

The amount of honey that a colony will need from the time it is packed until it is unpacked can not be closely estimated. The aim of the beekeeper in winter should be to save bees rather than honey, and he can make no more profitable investment than to give his bees more than they can possibly use. Some beekeepers claim that it is best to have the old bees die soon, so as to save stores. The actual consumption in such badly wintered apiaries is probably not at all decreased.

If the bees do not have sufficient stores, they may be given combs of honey, but these should always be given before cold weather, so that a proper clustering space may be formed by the moving of honey, since bees always cluster in empty cells of the comb adjacent to stores.

If honey in combs is not available, the bees may be fed extracted honey, but the usual practice is to feed a thick sugar sirup made of 2 or 2½ parts of sugar to 1 part of water by volume. To this sirup 1 ounce of tartaric acid should be added for each 40 to 60 pounds of sugar while the sirup is being heated to the boiling point to dissolve the sugar crystals. The sirup should be boiled 15 minutes. The acid helps to invert the cane sugar, thus retarding its granulation in the combs. If there is any question as to the quality of the stores, it is a good practice to feed about 10 pounds of sirup at the time of packing, in addition to the stores provided earlier, this being stored immediately above the cluster. It is thus used first, and an accumulation of feces does not occur so long as the bees use only the sugar sirup. There is, however, no better food in winter than a good quality of honey. As was stated earlier, honey-dew honey causes a rapid accumulation of feces, resulting in dysentery. If this is present in the fall, it should be removed and better stores given. Some fall honeys are similarly injurious, but their injurious effects may be reduced by feeding sirup at the time of packing.

SUMMARY AND CONCLUSIONS.

Bees need protection from cold and wind in winter in practically all parts of the United States. The beekeeper should give abundant insulation, since it is impossible to give too much and since most beekeepers give too little. Great care should be exercised to protect colonies from wind. Every colony should be strong in the fall, so that heat may be generated and conserved economically. To reach the proper population a good queen is necessary.

Many colonies die of starvation in winter. This can easily be avoided.

The beekeeper can make no better investment than to give his colonies proper care for winter.

If the excessive winter losses are prevented, commercial beekeeping will be greatly benefited. Such a condition is entirely possible when beekeepers come to understand the fundamental principle of wintering.

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

HYDROCYANIC-ACID GAS AGAINST HOUSEHOLD INSECTS.[1]

By L. O. HOWARD, *Entomologist and Chief of Bureau*, and C. H. POPENOE, *Entomological Assistant.*

INTRODUCTION.

The purpose of this bulletin is to enable the reader to use hydrocyanic-acid gas safely and effectively as a means of destroying the various insect pests of the household, such as bedbugs, fleas, cockroaches, ants, clothes moths, and carpet beetles.

By way of caution it should be stated at the outset that hydrocyanic-acid gas is extremely poisonous and is fatal to human beings if breathed in any quantity, while the chemicals used in generating the gas—sodium cyanid or potassium cyanid and sulphuric acid—are also very poisonous, the cyanid being necessarily fatal if only a small piece be eaten and the sulphuric acid burning badly when coming in contact with the skin. Special attention is called to the full discussion of this subject on pages 6 to 8, under the heading "The cyanid and gas a deadly poison." *The chemicals must be handled with the greatest care and the fumigation process must not be undertaken until it is thoroughly understood in every particular.*

Hydrocyanic-acid gas has been for more than 20 years one of the most effective known fumigants in use against noxious insects. It has a wide range of applicability, including the control of scale insects on citrus and nursery stock and the fumigation of greenhouses and cold frames, and it is a standard remedy against insects in mills and warehouses.[2] As a fumigant against household insects it has

[1] A revision of Circular No. 163 of the Bureau of Entomology.

[2] Entomologists have long noticed that insects vary greatly in their susceptibility to cyanid fumes. The ordinary killing bottle used in making collections contains cyanid of potassium, or cyanid of sodium, covered with plaster of Paris, which the fumes of the cyanid penetrate. Certain weevils, especially hard-bodied forms, will frequently be left overnight in a cyanid bottle and recover after being removed. It has been noticed also that in greenhouses certain insects recover after fumigation with hydrocyanic-acid gas.

been in use since 1898 and has proved so uniformly effective for this purpose when properly applied that in spite of its extremely poisonous character it has almost entirely replaced other and less poisonous gases.[1] Rats and mice are also killed by its use, and it fortunately has the effect of first causing these animals to rush out from their holes into the open, so that the subsequent annoyance of dead rats and mice in walls and under floorings is not experienced. The absence of any bleaching or tarnishing tendency when pure materials are used is also a strong point in its favor.

MATERIALS USED IN THE FUMIGATION PROCESS AND THEIR PROPORTIONS.

In the formation of hydrocyanic-acid gas for the purposes of fumigation sulphuric acid in a diluted form is permitted to act on either sodium cyanid or potassium cyanid. In the resulting reaction hydrocyanic-acid gas is liberated, while the remainder of the salt unites with the sulphuric acid to form sodium or potassium sulphate, nonpoisonous compounds. Up to the year 1909 cyanid of potassium was used almost entirely for this purpose, but since that time cyanid of sodium has taken the place of potassium cyanid and the latter is not now easily obtainable.[2] Sodium cyanid in its pure form liberates nearly a third more hydrocyanic-acid gas per pound than does cyanid of potassium and is a satisfactory substitute for potassium cyanid. Its slightly greater cost is balanced by the larger yield of gas. Cyanid of sodium is now being manufactured in special 1-ounce molds for fumigation purposes.

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[1] Carbon bisulphid has sometimes been recommended as a substitute for hydrocyanic-acid gas. The extreme inflammability of this substance, however, and the explosiveness of its vapor when confined render it perhaps less available, and the danger in its use more than counteracts the danger to human beings from hydrocyanic-acid gas. It has been found, moreover, that hydrocyanic-acid gas is much more effective for the control of all groups of household insects, with the exception of the beetles, than is the other fumigant.

[2] Should potassium cyanid be obtainable, and used in the fumigation, 1 fluid ounce of commercial sulphuric acid (about 1.84 sp. gr., or 66° Baumé) diluted with 3 fluid ounces of water (to increase the bulk of the liquid and insure complete chemical action) and 1 ounce of high-grade (98 per cent) cyanid of potassium must be used for every 100 cubic feet of space. The formula per hundred cubic feet, therefore, is as follows:

Potassium cyanid (98 per cent)	avoirdupois ounce	1
Commercial sulphuric acid	fluid ounce	1
Water	fluid ounces	3

Potassium cyanid was formerly obtainable in various technical grades, ranging between 40 per cent and 98 to 100 per cent actual cyanid, the remainder being an inert salt, usually sodium carbonate or sodium chlorid, which is of no value in fumigation and in the case of sodium chlorid is a positive detriment, as this substance, acted upon by sulphuric acid, produces hydrochloric acid, which decomposes the hydrocyanic-acid gas. In cases of extreme adulteration as much as 60 per cent of the fumigant may be decomposed in this manner, resulting in inferior effectiveness and tending to tarnish polished metal surfaces exposed to the gas. If chemically pure cyanid is used little tarnishing results.

In the use of sodium cyanid the grade known as "98 to 99 per cent"[1] should be procured, and combined with the other materials according to the following formula:[2]

Sodium cyanid	avoirdupois ounce	1
Sulphuric acid	fluid ounces	1½
Water	do	3

In this combination sufficient sulphuric acid is added to liberate completely the excess hydrocyanic acid in the sodium cyanid, since in the use of this chemical a greater amount of sulphuric acid is necessary for the complete exhaustion of the cyanid.

For loosely constructed frame houses the foregoing amounts may be doubled for each 100 cubic feet. The cyanid costs from 25 to 50 cents a pound, and the sulphuric acid (thick or more sirupy commercial brand) about 4 cents a pound.

The purity of the cyanid and sulphuric acid to the degree indicated is essential to the success of the fumigation.

Druggists and other retail dealers generally have in stock only impure grades of sodium cyanid, used for other technical purposes but unsuitable for fumigation on account of the greater or less percentage of sodium chlorid (common salt) and other adulterants contained. The presence of salt, as noted in relation to potassium cyanid (see footnote[2], p. 2), greatly reduces the amount of hydrocyanic-acid gas given off, and it is therefore highly important to insist on the best commercial grade of sodium cyanid, known as 98–99 per cent, containing 51 per cent cyanogen, such as is manufactured especially for fumigation purposes. The greater amount of cyanogen (available hydrocyanic-acid gas) in cyanid of sodium necessitates the use of a correspondingly greater amount of acid, as indicated in the formula for sodium cyanid.

DIRECTIONS FOR FUMIGATION.

Before beginning the fumigation the house must be vacated. It is not necessary to remove any of the furniture or household belongings unless of polished nickel or brass, which may tarnish a little. Liquid or moist foods, as milk, meats, or other larder supplies that are not dry and might absorb the gas, should be removed from the house. All fires should be put out; for while the gas will not burn at the dilution employed in fumigation, it is as well to take no risks.

The cubic contents of each room on each floor should be carefully computed and a tabular statement prepared, such as the one given

[1] This grade was formerly known as 128–130 per cent cyanid, since an equal amount by weight of chemically pure sodium cyanid liberates 33 per cent more hydrocyanic-acid gas than does pure potassium cyanid, and this was expressed by designating the pure sodium cyanid as 133 per cent.

[2] For rapid work it may be stated that in either of the foregoing formulas, where the cyanid is weighed out in pounds avoirdupois, the same proportions may be used as expressed in the formulas, the acid and water being measured in pints.

below, designating for each floor and the different rooms the capacity and the amount of water, acid, and cyanid needed.

Table designating rooms, capacity, and amounts of chemicals.

Floor.	Room.	Cubic feet.	Water.	Acid.	Cyanid.
			Fl. oz.	*Fl. oz.*	*Avd. oz.*
Fourth	Garret	17,000	210	70	70
Third	Front	2,800	84	28	28
	Middle	1,400	42	14	14
	Back	2,200	66	22	22
Second	Front	15,500	165	55	55
	Middle	2,200	66	22	22
	Back	2,000	60	20	20
First	Parlor	14,400	132	44	44
	Middle	2,400	72	24	24
	Dining	2,900	87	29	29
Basement	Servant's	1,200	36	12	12
	Hall	2,000	60	20	20
	Kitchen	1,800	54	18	18
Total		37,800	1,138	378	378

The house is prepared for treatment by seeing that all the windows are closed and calked, if of loose construction, with wet paper or cotton batting tucked tightly into the crevices. Gummed paper strips are obtainable for this purpose and may be pasted over the crevices in the doors and windows, making the room practically gas-tight. As the building must be aired by opening the windows from the outside, those selected to be opened should be examined to see that they pull down easily, and if too high to be reached from the ground should be provided with strong cords reaching to the ground that they may be easily opened from below. They should be opened before closing for the last time in order to test the strength of the cord and should not be pasted up or calked. The fireplace flues in the different rooms should be stuffed with paper and the registers closed. Carpets and rugs should be cleared away from the floor as far as possible to prevent their being burned should the acid spatter or boil over.

For generators, stoneware or crockery jars having a capacity of 4 gallons are preferable and may be used with a charge of up to 3 pounds of cyanid. One of these vessels should be placed in each room, with the exception of large rooms requiring a charge of more than 3 pounds of cyanid, when the charge may be divided. One vessel will suffice for each 3,000 or 4,000 cubic feet, preferably the former amount. Under each of these vessels a larger vessel or a rather thick carpeting of old newspapers should be placed, and care must be exercised to see that none of the vessels is cracked, on account of the danger of breakage from the heat generated by the process. Deep vessels are more satisfactory for the experiment than the washbasins often used, but the latter are always available and will serve the purpose. Deeper vessels give greater depth to the

water and acid and accelerate the chemical action, and there is less danger of spattering. Whenever the room is of such size that much more than 3 pounds of cyanid must be employed for it, it is perhaps better to make two charges of half size for such room.

PROCESS OF FUMIGATION.

In the process of generating the gas the water may be measured in a glass beaker indicating ounces, or, for convenience, in a pint cup, and poured into the generators. The acid, measured in the same receptacle, is then slowly and gently poured into the water to avoid splashing or boiling. For all ordinary purposes 1½ pints of the acid and 3 pints of water are sufficient for each pound of sodium cyanid. *The acid should never be placed in the generators first, as advised by some writers, since experience shows that this is dangerous, spattering being almost certain to follow.* When the acid is poured into the water in the jar an ebullition of vapor sometimes arises. Considerable heat is also developed by the addition of the acid.

When the cyanid, which previously should be broken into pieces the size of an egg, is finally dropped into the combined acid and water mixture bubbling takes place similar to that produced by a red-hot iron dipped into cold water. The generation of hydrocyanic-acid gas, the most poisonous gas in common use, begins at once. The gas is colorless and has an odor which has been likened to that of peach kernels. This odor is decidedly metallic, like that produced by striking two pieces of metal together, or of metal against stone. If the fumes are inhaled in any considerable quantity they are almost certain to prove fatal; hence the necessity of extreme care and the advisability of the presence of two intelligent operators in this work. It is even advisable, especially when the first fumigation is undertaken, that one who has had experience with this method of fumigation be present to give directions.

The measuring and preparation of the water and acid in the fumigating jars should be undertaken in a room with a tile or concrete floor if possible, as the strong acid used is apt to injure wooden floors or carpets should spilling occur. The jars may then be distributed to the different rooms and a bag containing the requisite cyanid placed by the side of each.

The house is now in readiness to be fumigated. Coats and hats and everything needed outside must be removed, and preferably two persons should then go to the top of the house, taking different rooms on the same floor to expedite the process, and place the bags containing the cyanid gently into the vessels to receive them. The chemical action will begin at once, but the gas will not rise to any extent for a few seconds or a quarter of a minute, and there is ample time to leave the room quickly without danger of breathing the gas. Having

finished the garret or top floor, the operators should pass rapidly to the next, and so on to the basement, making their exit through the lower door to the street.

Hydrocyanic-acid gas is lighter than air, and consequently rises; therefore the operation must be begun at the top of the house.

The house should be locked from the outside and, if necessary, a warning sign put up to caution against entrance.

The preparation of the different rooms, getting their cubic contents, placing the vessels, and preparing the charges, in a house of the size indicated in the foregoing table, will take from two to three hours, and this much time must be allowed for. The house should remain closed, for the gas to become fully generated and do its work, for from 4 to 6 hours at least—preferably, however, and to get the greatest efficiency, for 24 hours.

Better results are claimed for a warm temperature, say, 70° F. or above, than in a temperature as low as 50° F. or below. Under 50° most insects become torpid, and the effective action of the chemical will be diminished, especially in very low temperatures.

At the close of the operation the doors may be opened and the windows lowered or opened from the outside, and after an hour's airing the house may be entered, if no strong odor of gas is detected, and opened up even more thoroughly, if possible, to allow a complete airing for several hours. The house should not be reinhabited until all traces of the odor of the gas have disappeared. This odor, as stated before, has been compared to that of peach kernels.

The contents of the generating jars should be poured into the sewer trap, or disposed of in some place where they will not be a source of danger, and the jars thoroughly cleaned.

THE CYANID AND GAS A DEADLY POISON.

In the use of hydrocyanic-acid gas for household fumigation we must not for a single instant lose sight of the fact that we are dealing with one of the most poisonous substances known; that the accidental eating of a small portion of cyanid will necessarily be fatal; and that the inhalation of a few breaths of the gas will asphyxiate, and, if rescue be not prompt, have a fatal termination. It is much better, therefore, if fumigation be contemplated, to put the work in the hands of some one who has had experience, if such a person be available; if not, to consider carefully all the recommendations and precautions in this bulletin and become thoroughly familiarized with them before undertaking the experiment.

While the writers thus strongly emphasize the dangerous and even fatal qualities of this gas when breathed by human beings, it is worthy of remark that in the thousands of operations which have been carried on with this gas in different parts of the world only

three cases of fatal accidents to human beings have been recorded. These were due to extreme carelessness in its use. In one case the operator went back into the house after having dropped the bags and closed the building for some time. The abundant experience which has been gained by the different members of the force of the Bureau of Entomology and many others in the fumigation of dwelling houses has demonstrated that all danger is easily overcome by care in conducting the operation. In all the house-fumigation work which has been done during the last 10 years no accident has occurred, except in one or two instances the burning of rugs in attempting to set off charges in too small vessels and a case of headache where a few whiffs of much diluted gas had been accidentally breathed.

It follows, from what we have just said, that there may be danger from fumigating one house in a row of houses separated only by party walls, the other houses being inhabited. Unnoticed cracks in a wall would admit the poisonous gas to the neighboring house. In such a case a householder must consult his neighbors. In isolated houses, however, with the precautions indicated, the operation will be a safe one. The fact that birds resting on the ridge of houses in which the gas was being liberated have been killed by the ascending fumes indicates also that where the house to be fumigated immediately adjoins a higher structure to which the gas may possibly gain entrance there may be some danger to the occupants of the higher structure.

Single apartments or rooms in buildings should not be fumigated except when the whole building can be vacated during the operation. In case of contiguous houses of loose construction an arrangement should be made so that the adjoining houses also may be vacated during fumigation.[1]

In handling the acid great care should be used in pouring it from the bottle and in putting it into the vessels to avoid spattering on the hands or face, since it will burn rapidly through the skin, and should it spatter into the eyes would cause serious inflammation or loss of sight, or if on the clothing it would burn a hole in the garment. Should a drop fly to the hands or face, bathe the part promptly and freely in water, and the same also for garments or the carpet. It is further desirable to have at hand a bottle of ammonia to neutralize the acid should it spatter on clothing.

The handling of the dry cyanid is not accompanied by any danger if there be no open wound on the hand, but it is advisable to wear an old pair of gloves in breaking up the cyanid and putting it into the

[1] One of the fatalities mentioned in a preceding paragraph resulted from the fumigation of a basement in an apartment house not only without seeing that these apartments and the entire building were vacated and closed during the operation, but without even warning the occupants in the apartments above.

sacks, these gloves to be afterwards burned. The fact that the cyanid has a superficial resemblance to sugar adds to the danger of keeping it about the premises, and it is much better at once to bury deeply or throw down the sewer trap any left-over cyanid.

SUMMARY OF METHOD.

The general directions for treatment may be briefly summarized as follows:

(1) Prepare tabular statement designating room capacity and amount of chemicals for each compartment and secure the chemicals and vessels for generating the gas.

(2) Arrange for the opening of doors and windows from the outside at the conclusion of the fumigation and close all registers, fireplaces, and other openings. Do necessary calking and remove carpets and rugs and moist food material and any metallic objects which are likely to be tarnished.

(3) Place the generating vessels in each room with a thick carpeting of old newspapers under each.

(4) Break up the cyanid out of doors and place it in thin paper sacks containing charges suited to the amounts to be used in the different rooms.

(5) Measure into each of the generating jars the proper amount of water and afterwards add the acid slowly in the proper amount to each of the jars.

(6) Take the cyanid in bags in a basket and place the bags containing the proper amount alongside of the generating jars in each room.

(7) Start at the top of the house and place the cyanid gently, so as not to spatter, into each jar and quickly leave the room. As soon as the upper floor is finished go to the next lower, and pass in this manner from floor to floor until the basement is reached and exit is made through the lower door. If two persons work together in this operation they should both be on the same floor together, taking different rooms.

(8) The following day, or after the completion of the fumigation, open the windows and doors from the outside and let the house ventilate for an hour before entering it.

(9) After the house is thoroughly ventilated and the odor of the gas has disappeared, empty the jars in a safe place, preferably through the sewer trap, and wash them thoroughly and repeatedly before using them for any household purpose.

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE BAGWORM, AN INJURIOUS SHADE-TREE INSECT.[1]

By L. O. HOWARD and F. H. CHITTENDEN.

CONTENTS.

GENERAL APPEARANCE AND NATURE OF ATTACK.

Shade trees, shrubs, and hedges, and in particular evergreens, are much subject to injury by a caterpillar which has a curious habit of crawling about on the infested trees in a baglike case, whence its common name of bagworm or basket worm.[1] In the shelter of these cases the insects undergo all their transformations, after which the bags remain attached to the plants for some time and are conspicuous objects on leafless trees and shrubs in late autumn and in winter. Like the tussock moth[2] and the fall webworm[3] this species is preeminently a pest on trees and shrubs along streets and in parks and private grounds of cities and towns and even more than these is subject to fluctuation in numbers. It is, however, more limited in distribution than the two insects mentioned and not found as a rule

[1] *Thyridopteryx ephemeraeformis* Haworth; order Lepidoptera and family Psychidæ.
[2] *Hemerocampa leucostigma* S. & A.
[3] *Hyphantria cunea* Dru.

NOTE.—This bulletin is suitable for distribution in the southeastern portion of the United States.

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north of southern New York and the central portions of Pennsylvania and Ohio. South of these points it is in certain years very troublesome and the subject of much complaint. Such a year was 1907, when the bagworm attracted greater attention than any other tree defoliator. Numerous complaints were received of injuries in the region mentioned, especially from the States of New Jersey, Pennsylvania, Maryland, Virginia, West Virginia, Ohio, Indiana, and Illinois. The natural enemies of this insect (see p. 7) were comparatively scarce, and there is a strong possibility of a recurrence of injuries in the years to come.

FIG. 1.—Bagworm (*Thyridopteryx ephemeraeformis*). Natural size. (After Riley.)

The general appearance of the bagworm is shown in figure 1, which illustrates the caterpillar when nearly full grown in its characteristic bag. When removed from its bag it looks as shown in figure 2, *a*, which represents the full-grown larva. At this period in its development it may attain a length of about three-fourths of an inch. The body is soft in texture and dull brownish or blackish, while the head and thoracic segments are horny and whitish, mottled with dark brown.

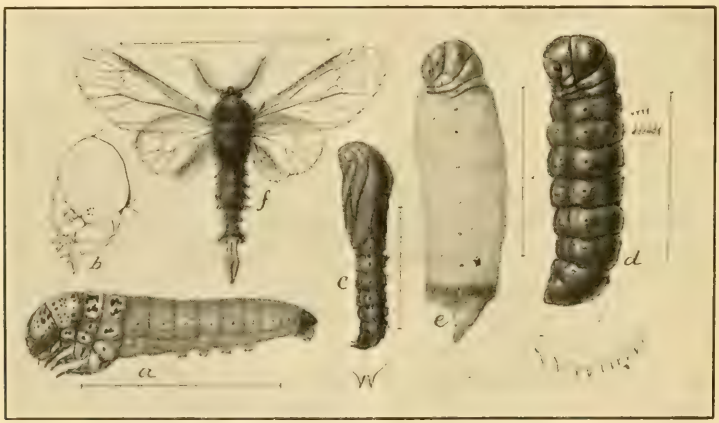

FIG. 2.—Bagworm (*Thyridopteryx ephemeraeformis*): *a*, Full-grown larva; *b*, head of same; *c*, male pupa; *d*, female pupa; *e*, adult female; *f*, adult male. All somewhat enlarged. (From Howard.) N. B.—The various stages are in reality a trifle longer than they are shown by the hair lines.

ORIGINAL HOME AND PRESENT DISTRIBUTION.

The bagworm is unquestionably native to North America. It abounds in the Southern States, except in the immediate Gulf region,

but is found farther to the north, and there are indications that it has gradually spread into this territory from more southern regions.

The map (fig. 3) which shows the region in which injury by the bagworm has been reported up to the year 1907 by black areas, and again during the two years 1913 and 1914 by shaded areas, as authenticated by the files of the Bureau of Entomology, may indicate that the species tends to spread toward the south and west. This apparent tendency, however, may be due merely to the planting of more trees in the more thickly populated towns and cities in such States as Oklahoma.

FOOD PLANTS.

The bagworm, although a very general feeder, displays a particular fondness for evergreens of all kinds, especially for arbor-

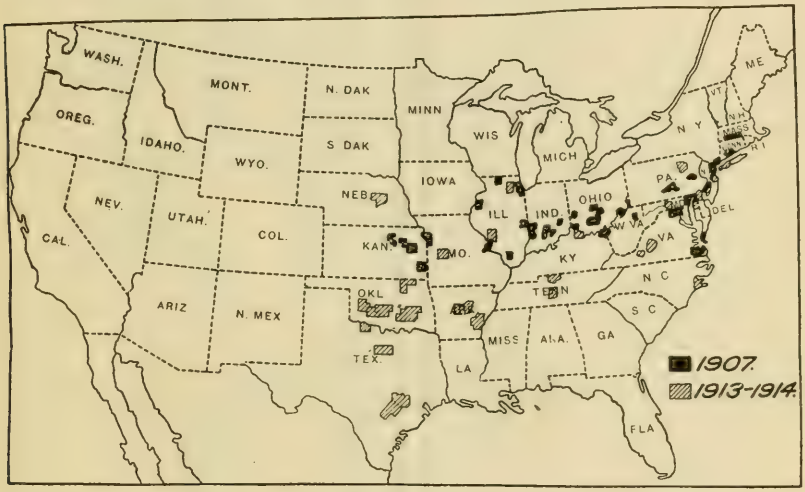

FIG. 3.—Map showing, by black areas, localities in which injury by the bagworm has been reported up to 1907 and, by shaded areas, those in which injury was reported in 1913 and 1914. (Original.)

vitæ (fig. 4); hence it seems probable that one or the other of these was its original or normal food plant. The species becomes exceedingly abundant every few years, and at such times it may be found on shade, orchard, and forest trees of nearly every kind. It is fond of willows and maples, particularly the silver maple and its varieties and the related boxelder; it is also fond of the poplars and mulberry, less so of the elms, and apparently still less so of the oaks. It feeds more or less freely, however, on most other trees and shrubs, and even on many low-growing semiwoody plants, such as elder, mallow (Hibiscus), and ragweed.[1] Thus in the absence of its choice food plants it is able to subsist on the foliage of almost any of the

[1] *Ambrosia trifida.*

FIG. 4.—Arborvitæ infested by bagworms. (Authors' illustration.)

plants of the character enumerated which may be available, but it does not seem to live on grasses and herbaceous plants generally.

HABITS AND LIFE HISTORY.

The bagworm overwinters in the egg stage within the old female bag, and for this reason hand picking in wintertime is an efficacious remedy. In the late spring the young hatch from the eggs, crawl out upon the twigs, make their way to the nearest leaf, and immediately begin to feed and to construct cases or bags for themselves. They spin a large quantity of silk, and attach to it for additional strength and protection bits of leaf or twig, evidently attempting to disguise the nature of the case as well as to strengthen it. The larva is remarkably soft-bodied, except for its head and strong thoracic plates, and it is necessary that the soft abdomen should have some protection.

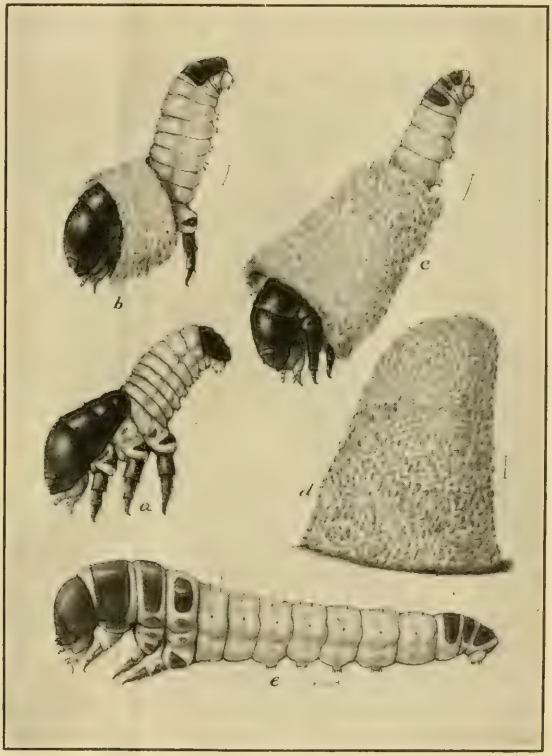

FIG. 5.—*a*, Newly hatched bagworm before making its case; *b*, same, just beginning case; *c*, same, with its case nearly completed; *d*, completed case, insect concealed within; *e*, larva after first molt. Highly magnified. (Authors' illustration.)

The construction of the bag of an allied species of similar habits has been described as follows: The young larva cuts off with its jaws a small fragment of leaf which it places between its front legs, gradually forming a pile fastened loosely with silk. When the pile becomes a transverse tangle about as long as the body, it is fastened at each end loosely to the surface upon which it rests; then the caterpillar, after placing itself at right angles, dives under the

mass, turning a complete somersault, so that it lies on its back, bound down by the fillet. It then twists around and stands upon its feet, having its neck under a sort of yoke. It makes the yoke into a complete collar, adding bits to each end until the circle is complete. Then row after row of fragments is added until the case becomes a hollow cylinder. One end is then closed up, and the inside lined with a tough coating of silk, the case being then extended upright and fastened at one end. When it is fully completed, the larva crawls away with the case carried upright like a cap on the upturned end of its body.

Figure 5, *a–c*, shows stages in the construction of the case and *d* a completed case made by the young larva, tightly appressed to the flat surface, the larva being concealed within. Such bags may frequently be found on leaves, and are quite puzzling to the uninitiated until the larva pokes out its head and slowly walks off.

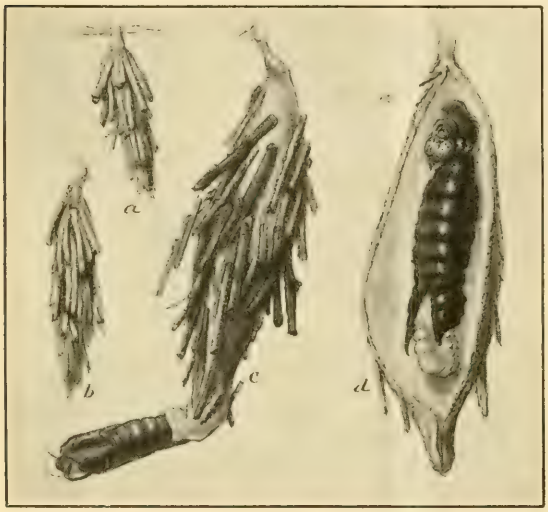

FIG. 6.—Bagworm at (*a*, *b*, *c*) successive stages of growth. *c*, Male bag; *d*, female bag. About natural size. (From Howard.)

As the caterpillar grows, the case is constantly enlarged, bits of twigs and any other small objects being used to ornament the outside, and these objects will vary with the kind of tree upon which the caterpillar is feeding. While the larva is small, it carries its case erect, but when it is larger the case hangs down (see fig. 1). The larval skin is cast four times, and during the molting the mouth of the bag is kept closed with silk. There is a small opening in the extremity of the bag through which excrement and cast skins are pushed. The male bags reach a length of about an inch, while those of the female are much larger.

Toward the end of August, about Washington, D. C., the larva completes its growth, attaches its bag firmly by a silken band to a twig, strengthens it inside with an additional layer of silk, and within this retreat, which now becomes its cocoon, transforms to pupa with its head downward.

The pupal period lasts about three weeks, and then the adult emerges. The male chrysalis works its way out of the lower opening,

and the winged moth issues through the cracking skin, leaving the chrysalis hanging from the bag, as shown at *c*, figure 6. The chrysalis of the female does not push its way at all out of the bag, but the skin cracks and the female gradually works her way partly out of the chrysalis skin, her head reaching the lower end of the bag (fig. 6, *d*). The males fly about seeking the bags of the females, and when one is found in which the head of the female is near the end, showing that she has emerged from her chrysalis skin, the male mates with her. The female then works her way back into the chrysalis skin, gradually filling it with eggs until more than half of it is filled, scattering in among the eggs some of the sparse hairs from her body. Having done this, she forces her shriveled body out of the opening, falls to the ground, and dies. The eggs remain in this way until the following spring when they hatch as previously described. There is thus only one generation annually.

FIG. 7.—*Itoplectis inquisitor:* Female from side. Enlarged. (From Howard.)

FIG. 8.—*Allocota thyridopterigis.* Much enlarged. (Authors' illustration.)

NATURAL ENEMIES.

Although apparently well protected from the attacks of birds by its tough case, the bagworm is somewhat extensively parasitized by several forms of ichneumon[1] and chalcis flies,[2] most of them species which affect also similar tree-feeding caterpillars.

REMEDIES.

When the bagworm occurs upon deciduous trees it can be controlled by hand picking the bags in the winter, but when it affects evergreen trees it is practically impossible to apply this

[1] (*Pimpla*) *Itoplectis inquisitor* Say (fig. 7), (*Pimpla*) *Itoplectis conquisitor* Say, and (*Hemiteles*) *Allocota thyridopterigis* Riley (fig. 8).

[2] *Spilochalcis mariae* Riley (fig. 9), *Chalcis ovata* Say (fig. 10), *Dibrachys boucheanus* Ratz. (fig. 11), and *Habrocytus thyridopterigis* Ashm. (fig. 12). Certain of these species are undoubtedly hyperparasitic; that is, parasites of the bagworm parasites.

remedy with profit unless the plants are badly defoliated. Therefore, for the treatment of evergreens, spraying is a necessity.

The methods of controlling shade-tree pests in cities and towns[1] are in part applicable to this species.

COLLECTING THE BAGS.

One of the most important remedies consists in gathering the bags with the contained insects by hand and either burning them or preserving them to liberate the useful parasites which have been previously mentioned. This work may be facilitated by the use of a 12-foot pole pruner or similar appliance. Where the trees are very tall it will be necessary to use a long ladder. For best results the cooperation of neighbors who are troubled with the same pest should be secured. Considerable immunity from future injury will result by care in the employment of this method. It is particularly useful where only a few trees are infested. The bags are such conspicuous objects on defoliated or bare trees in winter that it is not at all difficult to detect them, but in cases where comparatively few insects are present on evergreen trees they are not so easily seen.

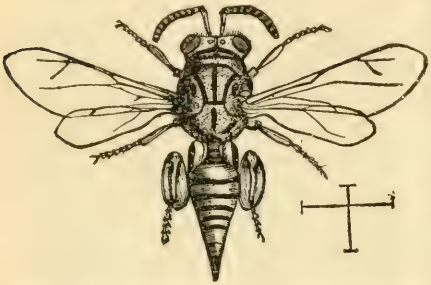

FIG 9.—*Spilochalcis mariae.* About four times enlarged. (After Riley.)

ENCOURAGING THE PARASITES.

When many trees are infested it is advisable to keep the hand-picked bags for a considerable time in receptacles, such as barrels covered with netting, preferably wire netting, so that the numerous beneficial parasites of the pest will be able to issue in the spring and assist in the control of the bagworm the following year. One or two holes bored in the bottom of the barrel or box will prevent water from accumulating and drowning the insects. Where the bags can be placed in piles in an open space or inclosure distant from trees and free from disturbance, the young insects, having very limited powers of locomotion, will soon perish of starvation, as they will not be able to find the trees or shrubs after they hatch.

SPRAYING WITH ARSENICALS.

On evergreens, where the bags are more or less difficult to find, hand picking can not be advised. A striking instance of the futility

[1] Howard, L. O. Three Insect Enemies of Shade Trees. U. S. Dept. Agr., Farmers' Bul. No. 99, 32 p., 11 fig., 1899. This publication may be had free on application to the Department of Agriculture.

of this method under such circumstances was given by a former Government entomologist at a conference on the gipsy moth in 1891. He said that he once tried to protect a cedar tree not more than 6 feet high, upon his own grounds at Washington, by hand picking. He worked during two consecutive months picking off small bags from that tree, the progeny of not more than two females. Almost daily he went to the tree and found fresh specimens which he had overlooked the day before. For evergreen trees, therefore, an arsenical spray is the best remedy. Injury by the bagworm on large trees has been absolutely stopped by spraying with Paris green at the rate of 1 pound to 150 gallons of water, the trees being completely rid of larvæ. It is easier to reach the bagworms on evergreen than on large-leaved deciduous shade trees, such as maple and elm, but if carefully carried out, spraying will result in the destruction of the bagworms, so that the collection of the bags in winter will not be necessary. Arsenate of lead at the rate of 1 pound of the prepared paste form to from 25 to 50 gallons of water will be found even more effective than the Paris green, as its greater adhesiveness renders it less likely to be washed off by rains, which in some seasons frequently occur almost daily at the time when the larvæ are beginning to work.

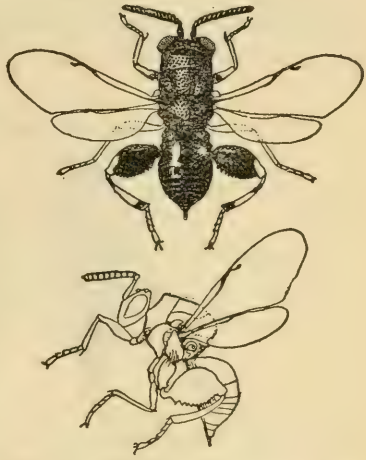

FIG. 10.—*Chalcis ovata:* Adult. Enlarged. (From Howard.)

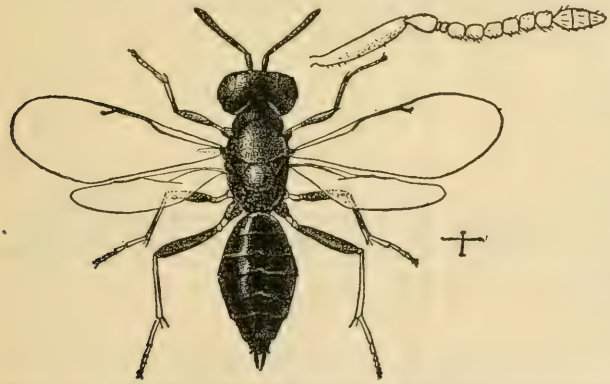

FIG. 11.—*Dibrachys boucheanus:* Adult female and antenna of male. Much enlarged. (From Howard.)

Arsenate of lead is not at all likely to produce scorching of the foliage of shade or ornamental trees or shrubs. Its natural adhesiveness is enhanced by the addition of about the same quantity by weight of resin-fishoil soap as of the arsenical used.

The question as to the best spraying apparatus to be used is an important one, the prime object being to destroy the insect without injuring the plant; the second, to avoid useless waste of the poison. Hand pumps and sprayers are unsatisfactory. One of the best types of orchard sprayer is desirable. This usually consists of a tank of about 100 gallons capacity equipped with a pump driven by a gasoline engine, mounted on a strong cart or wagon fitted with the proper length of hose and drawn by either one or two horses. Frequently one operator is enough, but two are better for most purposes, especially in the case of high trees.

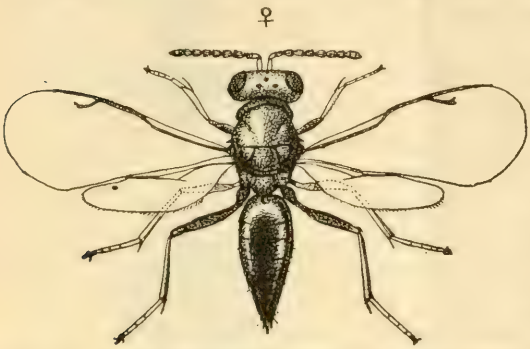

FIG. 12.—*Habrocytus thyridopterigis.* Greatly enlarged. (From Howard.)

In regard to nozzles, the older types, such as Vermorel and Bordeaux, may be used, but the new solid spray or Worthley type (fig. 13) is preferable. In case tall shade trees in valuable parks or woodlands are to be treated—trees such as spruce, cypress, hemlock, and willow, as well as maples—high-power sprayers are preferable. The type which has given the most satisfactory results in the gipsy-moth work can develop sufficient power to carry a stream which breaks into a fine mist in the air, and this is very satisfactory in rapid treatment. With such a sprayer it is not necessary to climb trees or to use small lines of hose or turrets.

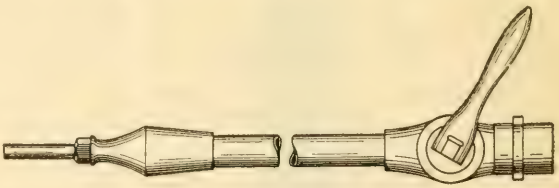

FIG. 13.—Solid spray or Worthley type of nozzle, and cut-off. (Original.)

In the treatment of a great number of trees a greater strength, namely 2 or 3 pounds of arsenate of lead to 50 gallons of water or Bordeaux mixture, is desirable, as the bagworms do not feed in masses and the poison must be directed so as thoroughly to coat and remain on the foliage where it will be eaten with the leaves. The treatment should be thorough and the application made evenly in order to secure the best results. Recent inquiry has elicited the information that arsenate of lead is being used with the highest power sprayers even at the rate of 10 pounds to 50 gallons of water, which

we consider an unnecessary expenditure. Moreover, if two or three applications are made—and this is often desirable in case this or other insects continue to injure the trees—it is almost certain to affect injuriously or destroy some forms of tender leafage if made at this strength.

The best time to apply either of the arsenicals mentioned, as in the case of most insects, is at about the time when the eggs hatch or a day or two afterwards.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 705 FEBRUARY 16, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE CATALPA SPHINX.[1]

By L. O. HOWARD and F. H. CHITTENDEN.

INTRODUCTION.

Our native species of catalpa, the common or eastern catalpa[2] and the hardy or western species,[3] are comparatively free from insect attack. Such common shade-tree pests as the bagworm[4] and fall webworm[5] occasionally feed upon the leaves, but apparently do so only in the absence of food more palatable to them. There is one insect, however, the larva or caterpillar of the catalpa sphinx (fig. 1, *b*, *c*, *e*, *f*, *h*),[1] which feeds normally and exclusively on the foliage of these trees and in some seasons does very considerable injury, often completely stripping the leaves from individual trees and sometimes from an entire grove. (Fig. 2.) Owing doubtless to the increased planting of these trees outside the regions in which they are found in the wild state, this insect has extended its natural range, and its injury is more widespread now than formerly.

DESCRIPTION.

The catalpa sphinx in its active feeding stage is a caterpillar fully 3 inches in length. It is very variable in color, there being a light and a dark form, as in the case of some related species. The prevailing colors are yellow and black, and this, combined with the large size of the insect, makes it a conspicuous object on infested trees. The complete life history by stages or periods of growth is well illustrated in figure 1.

[1] *Ceratomia catalpae* Bdv.; order Lepidoptera, family Sphingidae. [2] *Catalpa catalpa.* [3] *Catalpa speciosa.* [4] *Thyridopteryx ephemeraeformis* Haw. [5] *Hyphantria cunea* Dru.

NOTE.—This bulletin is of interest throughout the United States wherever catalpa trees occur.

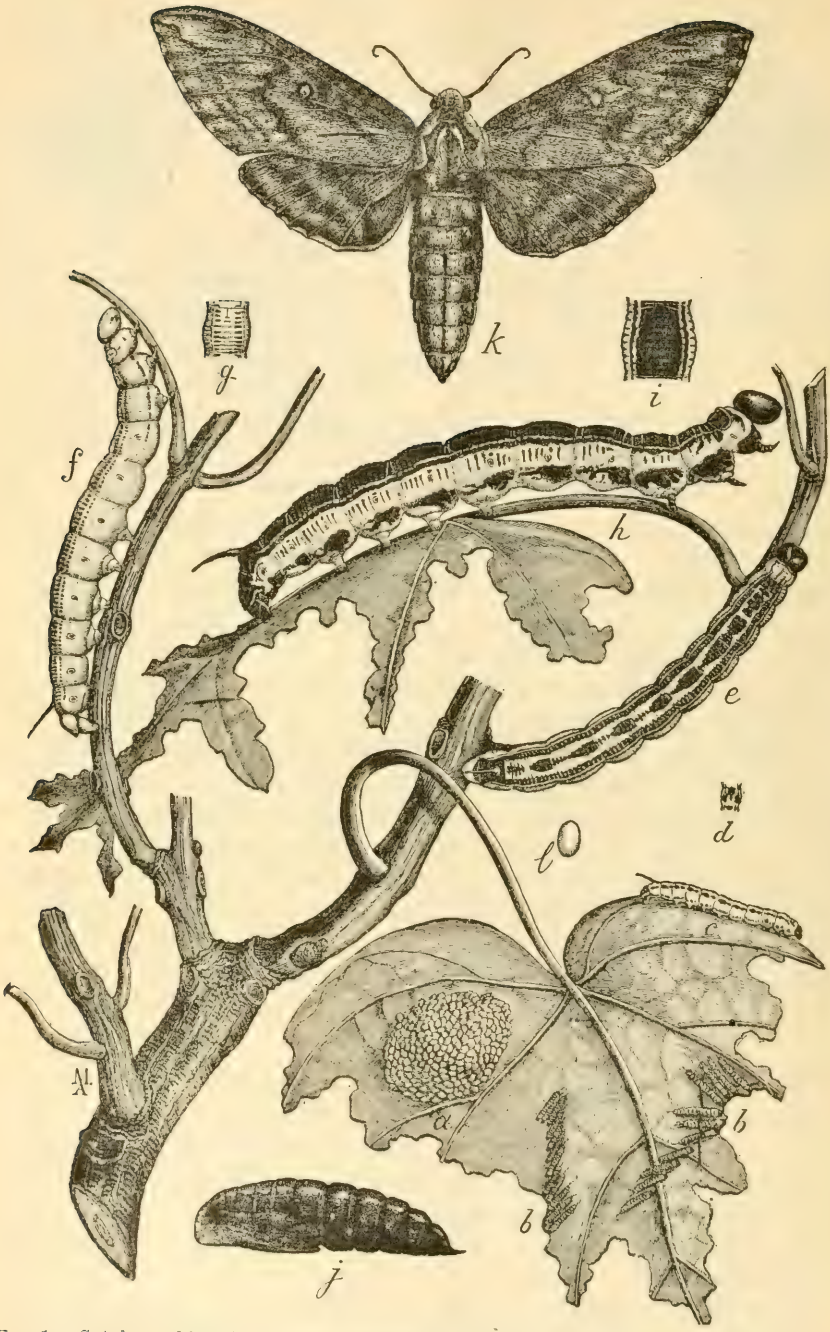

FIG. 1.—Catalpa sphinx (*Ceratomia catalpae*): *a*, Egg mass; *b*, *b*, newly hatched larvæ; *c*, larva one-third grown; *d*, dorsal view of joint of *c*; *e*, *f*, two differently marked, nearly full-grown larvæ; *g*, dorsal view of joint of *f*; *h*, full-grown dark larva; *i*, dorsal view of joint of same; *j*, pupa; *k*, moth; *l*, egg, enlarged. All natural size, except *l*. Marx del.

The parent of the caterpillar is a large grayish-brown hawk moth, marked as shown in figure 1, *k*. It has a large, heavy body and powerful wings which measure 3 inches from tip to tip when spread. It lays its eggs in masses, in which respect it differs from other hawk moths. An egg mass is shown in the illustration at *a* and an individual egg at *l*. The young caterpillars are lighter colored than the mature ones, being pale yellow. Two striking variations of the larva

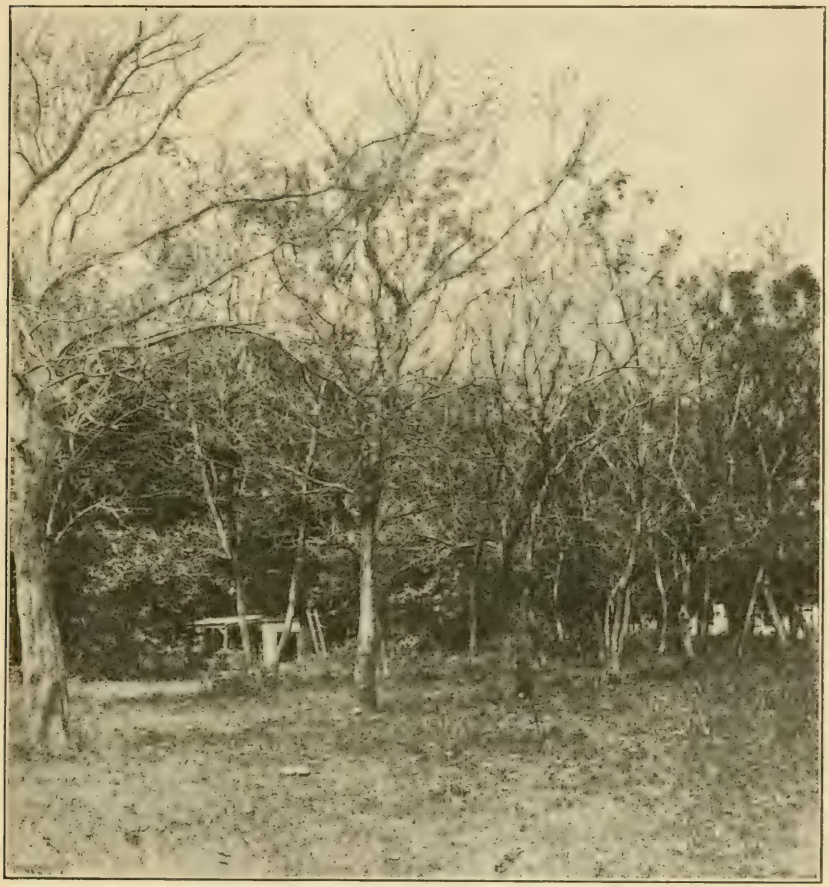

FIG. 2.—Catalpa trees showing excessive defoliation by the catalpa sphinx. (Original.)

in the later stages are shown at *f* and *e*, while *h* represents the commonest dark form of caterpillar. The larvæ have a stout black horn near the hind end of the body.

ORIGINAL HOME AND PRESENT DISTRIBUTION.

The known distribution of the catalpa sphinx at the present time (1915) is shown in figure 3. This insect is strictly a North American

species, and its range was given in 1888 as from "Virginia to Florida; westward to the Mississippi; as far north as Indiana." It is common in Virginia, Maryland, and Ohio, and of late years it has extended its range northward on the Atlantic coast and has been received from several localities in southeastern Pennsylvania, New Jersey, Ohio, Kentucky, and Delaware. It has spread northward in Delaware and has greatly increased in numbers where it was formerly rare. Its northward range appears to be limited in the West by Illinois.[1] This species was observed in Alabama in 1883, was received from Denison, Tex., in 1889, and was reported from Arkansas in 1900. By 1906 it had become established at Elberon and Bloomfield, N. J., the latter, westward and a little north of New York City, being the northernmost point of which we have knowledge of its occurrence in the East. It has since been reported from Burlington, N. C., Jericho Springs, Mo., and Wetmore, Tenn.

Fig. 3.—Map showing the known distribution of the catalpa sphinx in the United States in 1915. (Original.)

LIFE HISTORY AND HABITS.

The catalpa sphinx is subject to considerable fluctuation in numbers. For one, two, or even several years it will not be seen in a given locality and will then suddenly appear in large numbers, completely defoliating the trees and covering the ground beneath with larval excreta. It is interesting to observe that John Abbot, who collected the type specimens in Georgia, mentioned the fact more than a hundred years ago that fishermen who inhabited the borders of the swamps hunted for these larvæ as the best bait for catching fish, and

[1] The range of its food plants is as follows: From the Gulf of Mexico in western Florida, and on the rivers in Alabama and Georgia, westward and northward along the Mississippi and its southern tributaries in the great delta formation to above the mouth of the Ohio; thence up the Wabash and White rivers of Indiana to near Vincennes. This was formerly taken by entomologists to indicate also the range of the catalpa sphinx. Published records, however, were lacking until recently to show its general occurrence west of Florida and Georgia along the gulf.

it is said that this bait is so esteemed for this purpose in some parts of Florida that the catalpa is often cultivated for no other purpose than to attract the insect.

The eggs, as has been stated, are laid in masses, and the young larvæ feed in groups for some time. The capacity of the species for multiplying may be judged from the fact that an egg mass in the collection of the United States National Museum contains nearly 1,000 eggs. The mass is not compact, however, and is but slightly fastened to the underside of the leaves. Sometimes the eggs are laid in smaller masses on the stems and branches. The larvæ molt four times, becoming variable in their markings as they grow older. In the extreme South the insect is reported as being found in all stages during the summer, and there are three or four generations a year, the last generation wintering in the pupal stage beneath the ground and giving forth the moths the following March. In the summer, according to observations made in Florida, the time occupied by a complete generation is about six weeks. Around Washington, D. C., at Coalburg, W. Va., and probably everywhere in its southern range, there are two generations annually.

NATURAL ENEMIES.

A number of parasitic insects attack and kill the catalpa sphinx. *Apanteles congregatus* Say, a common, widespread, and very general parasite of sphinx caterpillars throughout the eastern United States, attacks this species quite as freely as it does the hornworms of tobacco and tomato. Unfortunately, this parasite is in turn attacked by other parasites, two species of which[1] are recorded. These last, fortunately, do not seem to be generally abundant, hence the beneficial parasite flourishes in spite of their attacks. *Apanteles congregatus* is a minute, four-winged, wasplike insect which lays its eggs in the sphinx caterpillar. Its larvæ—white, maggotlike creatures—develop within the body of the caterpillar, and when full fed and ready for transformation each individual eats a hole through the skin of the caterpillar and spins its little white cocoon on the outside. Two hundred or more such cocoons may be seen on the body of a single caterpillar. After a few days the winged parasites issue from the cocoons to lay eggs and produce another generation of larvæ.

(*Apanteles*) *Microplitis catalpae* Riley, which appears to be especially a parasite of the genus to which the catalpa sphinx belongs, is also an enemy of this species, although, like the Apanteles, it is sometimes itself attacked by other parasites.[2]

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[1] *Mesochorus aprilinus* Ashm. and *Hemiteles mesochoridis* Riley MS.

[2] *Hypopteromalus tabacum* Fitch and (*Holcopelte*) *Horismenus microgastri* Ashm.

Two common species of tachina flies[1] attack the larva of the catalpa sphinx. These are general parasites of butterflies and moths, the former infesting 27 distinct species, the latter 22.

A few birds prey upon the caterpillar, but most of them evidently find it when full grown a rather tough morsel, the skin being especially thick and resistant and the insect a very muscular one, so that, in fact, it is difficult to crush one with the end of a cane. Among the birds which have been recorded as destroying this insect are cuckoos, the catbird, and the Baltimore oriole.

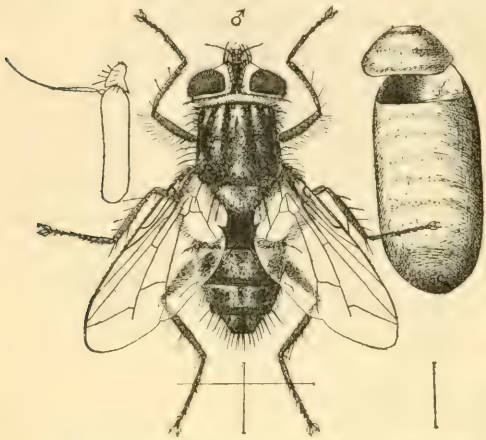

FIG. 4. One of the tachina flies, *Phorocera claripennis*, a parasite of the catalpa sphinx: Adult with puparium at right and enlarged antenna at left. (From Howard.)

REMEDIES.

There are several methods by which the catalpa sphinx may be readily destroyed. The caterpillars may be gathered by hand, the foliage of the trees may be sprayed with arsenical poisons, the pupæ may be destroyed by spading the ground around the tree trunks in the fall, and, indirectly, the sphinx may be destroyed by protecting the parasitic insects which attack it.

HAND PICKING.

Owing to its large size, the caterpillar is easily seen and can be controlled by hand picking. In the case of large trees a long ladder and a 12-foot pole pruner or similar device will be necessary in this work.

SPRAYING WITH ARSENICALS.

Where the caterpillars are injurious to trees of considerable height, rendering hand picking difficult, or where they occur in such abundance as to render probable the complete defoliation or stripping of the tree, the application of an arsenical spray is the best method for their control. Advantage may be taken of the gregarious habit of the young caterpillars by watching rather closely for their appearance in the spring, and if the leaves are observed to be eaten in any particular place, promptly applying an arsenical spray.

The arsenicals ordinarily used in the control of shade-tree insects are arsenate of lead and Paris green. If properly applied, neither of

[1] *Phorocera claripennis* Macq. (fig. 4) and *Frontina frenchii* Will.

these will be injurious to the leaves. In the preparation of these materials for spraying, the desired quantity of the chemical, usually 1 pound of Paris green or 3 pounds of arsenate of lead to 50 gallons of water, is weighed out and thoroughly mixed in a pail or other small container with a gallon or two of water. This mixture is then poured into a 50-gallon barrel, the remainder of the water added, and after having been strained through fine copper gauze for the removal of particles which might clog the nozzles, the spray is ready for use.

The application of the arsenate of lead or Paris green spray in combination with Bordeaux mixture is desirable, since the foliage of the catalpa is frequently infected by leaf spot[1] and by other similar diseases which may be controlled by the application of Bordeaux mixture. Moreover, in the presence of Bordeaux mixture no burning is likely to result, even to the most delicate foliage, through free arsenic in the Paris green or arsenate of lead used in the spray mixture. Bordeaux mixture may be prepared for this purpose as follows: In a barrel containing 25 gallons of water hang 6 pounds of blue vitriol or bluestone in a cloth sack. Four pounds of fresh stone lime should then be slaked in a pail or other container and water added until of about the consistency of whitewash. This mixture should then be poured into a second barrel with 25 gallons of water. In the usual preparation of spray mixtures 50-gallon barrels are used. After the bluestone has dissolved and the lime has been added to its respective quantity of water the two barrels may then be raised and simultaneously poured into a third one, the mixture being well stirred at the same time. After the preparation of the Bordeaux mixture according to this formula the requisite amount of Paris green or arsenate of lead is added and thoroughly stirred into the mixture.

A sprayer suitable for the control of the catalpa sphinx caterpillar, or other larvæ feeding on the leaves of catalpa or other trees of similar size and habit, might consist of one of the smaller power outfits such as are used in orchard spraying, or one of the large double-action hand pumps capable of furnishing a spray mixture to from three to five nozzles of the removable steel-disk type, using the large opening, at about 100 pounds pressure.

With the aid of a 10 to 12 foot tower on the wagon and an extension rod on the hose line, it will be possible to treat trees from 35 to 40 feet in height, which is about the maximum for the ordinary catalpa under cultivation. For trees of greater height a three-eighths to one-fourth inch nozzle of the Worthley type, supplied by a pump capable of delivering from 30 to 50 gallons a minute at a pressure of from 300 to 400 pounds, will be found necessary. Trees as much as 100 feet in

[1] *Phyllosticta catalpae.*

height have been sprayed in this manner from an ordinary sprayer tower. A high-power spraying outfit of the type used against the gipsy moth is shown in figure 5. Such a powerful stream will dis-

FIG. 5.—High-power spraying outfit for treating large caterpillars like the gipsy moth and catalpa sphinx. (From Burgess and Rogers.)

lodge many of the caterpillars. Particular attention is called to the upper end of the stream, in the illustration, where it breaks into a mistlike spray.

DESTRUCTION OF THE PUPÆ.

Where the caterpillars have been so abundant as to affect the trees, it will pay as a precaution for the following year to spade up the ground thoroughly and disintegrate it in the fall so as to destroy the pupæ, which will be found concentrated under the surface of the ground in the immediate vicinity of the trunk.

PROTECTING THE PARASITES.

The second or last generation, which appears in September and October, is largely destroyed by parasites which are frequently very abundant just as the oldest caterpillars are beginning to reach full growth. At this time the parasites, which have been previously mentioned, issue from the bodies of their host and spin large masses of white cocoons on the backs of the caterpillars. These masses are so large that they can be seen at a considerable distance against the black stripes of the host insect. It is not advisable to destroy the caterpillars at this stage, as the parasites are very beneficial and in ordinary seasons will reduce the numbers of the sphinx caterpillars so that they will not do much harm the following season. Where the caterpillars can be easily gathered it will pay to pick them from the leaves and transfer them to barrels or large boxes covered with wire netting. This will prevent the caterpillars from issuing or falling a prey to birds or other animals, and will insure the issuance of the parasites through the meshes, thus encouraging their good work. A few holes should be bored in the bottom of the barrels or boxes used, small enough to prevent the caterpillars from crawling through them into the ground. This will prevent the accumulation of water after rains, which might drown the insects or set up putrefaction in the mass.

COOPERATION.

If the cooperation of neighbors who have catalpa trees growing on their premises can be secured, this caterpillar can be largely controlled for several years in succession.

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FARMERS' BULLETIN

WASHINGTON, D. C. 708 FEBRUARY 14, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE LEOPARD MOTH:[1] A DANGEROUS IMPORTED INSECT ENEMY OF SHADE TREES.

By L. O. HOWARD and F. H. CHITTENDEN.

INTRODUCTION.

Along the Atlantic seaboard from eastern Massachusetts to southern New Jersey, and in the Hudson River Valley, shade and ornamental trees and shrubs of many kinds, with the exception of evergreens, are severely injured by the larva or caterpillar of the European leopard moth. Around such centers as Boston and New York, and in the State of New Jersey, this insect constitutes a most serious menace to the growth of shade trees. The larva of the leopard moth does not feed on the foliage, as do most of our shade-tree caterpillars, but bores into the branches and feeds upon the living wood. It usually begins operations in twigs and small branches and trunks; this work has the effect of girdling and so weakens the wood that the portion beyond the injury is often broken by heavy wind storms, while in the case of severe attack, especially to young trees, the growth of the tree is checked and death frequently follows. Attack is not confined solely to shade and ornamental plants, but orchards also are often injured.

DESCRIPTION.

The leopard moth derives its name from the spotted appearance of the adults as illustrated at *a* and *b* in figure 1. There is a great difference in size between the sexes, the female (*a*), which is a heavy-bodied moth and a very feeble flier, being much the larger. The male (*b*), on the other hand, has a more slender body, which insures ready flight, and is further distinguished from the female by the fact that its antennæ, or feelers, are broad and feathery. The wings are semi-

[1] *Zeuzera pyrina* Fab.; order Lepidoptera, family Cossidae. Synonyms: *Zeuzera aesculi* L. and *Z. decipiens* Kirby.

NOTE.—This bulletin is of interest to growers of shade and ornamental trees, especially in the New England and North Atlantic States.

transparent and white, thickly dotted with blackish spots which are more or less distinctly tinged, giving them a dark-blue or greenish cast. The thorax is white and has six large black spots and one small one, this last being in the center. The abdomen is white, with dark crossbands. The female has a wing spread of something over 1½ inches, while that of the male is much less.

The eggs are oval and salmon colored.

The larva, which is the form that inflicts the injury, is a fleshy, grublike caterpillar of pale-yellow color, very frequently with a pinkish tinge, especially when reaching full growth. The head,

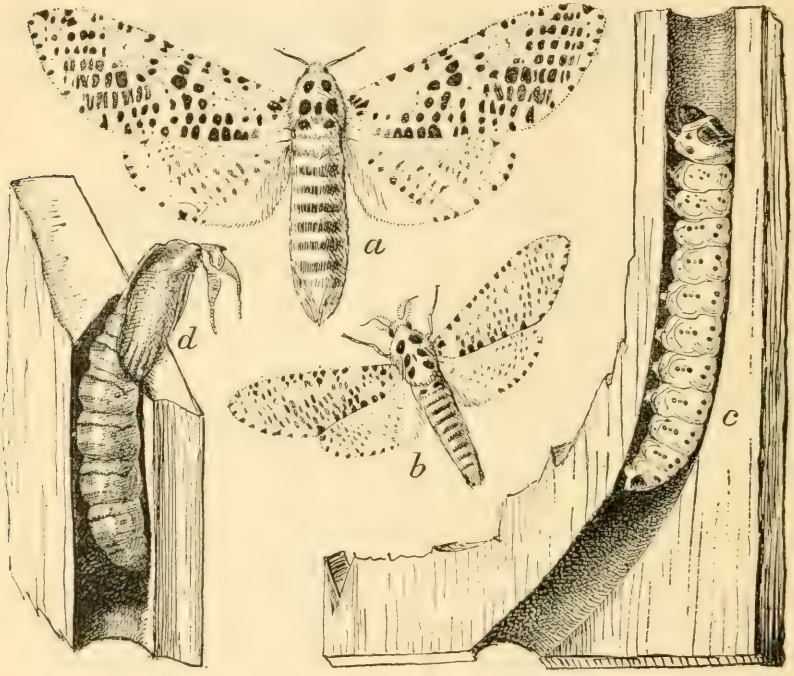

FIG. 1.—The leopard moth (*Zeuzera pyrina*): *a*, Adult female; *b*, adult male; *c*, larva; *d*, empty pupal case. Enlarged. (Authors' illustration.)

thorax, and plates on the hind end of the body above are brownish black, and the entire surface of the body is sparsely hairy and covered with large and prominent tubercles arranged as shown in figure 1, *c*, which illustrates the larva in natural position when at work in a tunnel which it has constructed in the solid living wood. When the larva has completed its growth it is fully 2 inches in length.

The pupa, or chrysalis, to which the full-grown larva changes, is very similar to that of other wood-boring caterpillars. On its head is a sharp protuberance which helps it in pushing its way partly out of the burrow preparatory to the emergence of the moth. The

appearance of the pupa is shown in figure 1 at *d*, which illustrates the empty pupal case projecting from the burrow, as the moth has left it.

ORIGINAL HOME; SPREAD AND PRESENT DISTRIBUTION.

The leopard moth, like so many other dangerous pests, is a European species which has been accidentally introduced into the United States in comparatively recent years. Its Old World distribution, as recorded, is central and southern Europe, southern Sweden, southwestern Africa, Algeria, northern Morocco, and the western portion of Asia Minor.

This species was introduced into the United States sometime prior to 1879; in this year a living moth was captured in a spider's web at Hoboken, N. J. In 1887 it was seen at Newark, N. J., but was not actually recorded as occurring in this country until the following year. In 1890 the moths were observed at electric lights at Orange, N. J. In 1894 its destructive ravages were recognized in Central Park, in New York City.

Fortunately the spread of this insect, particularly in the immediate vicinity of New York City, has been very slow, a fact which may be attributed to several causes: (1) The slow and feeble flight of the female, (2) the dominance of sparrows and squirrels in large cities, causing our native birds, such as woodpeckers, to be driven to the country, where they destroyed the moths, and (3) the bowl-shaped electric-light globes, open at the top and closed at the bottom, which were formerly in general use in our large cities. The males are strongly attracted to brilliant lights, and many were captured and perished in these globes in earlier years.

Specimens were collected at Bridgeport, Conn., in 1901. The species now occurs on Staten Island and has spread on Long Island well beyond the confines of greater New York. Southward it was reported a pest, in 1901, at Ocean Grove, N. J., and by 1905 was recorded at Kensico, N. Y., 25 miles north of New York City. By 1907 it was captured at New Haven, Conn. In 1908 it appeared in injurious numbers in the vicinity of Boston, Mass., where it seriously attacked the large elms on the Harvard University campus, and has since spread to more distant localities, specimens having been received from Lynn and from the island of Nantucket. It has been received from at least one locality in Rhode Island. Other towns and cities are indicated on the map (fig. 2), on which the southward limit, Woodbury, N. J., is shown.

On the occasion of a visit to New York City in recent years the junior writer was unable to find this insect or any evidence of its injury in the parks of Manhattan and Harlem. In side streets in the

vicinity of the parks, however, there were signs of extensive injury, and a number of trees had been removed, evidently because of death due to borer attack. Inquiry of the State entomologist and others failed to elicit any information in regard to new localities. The species has not been found in Pennsylvania so far as can be deter-

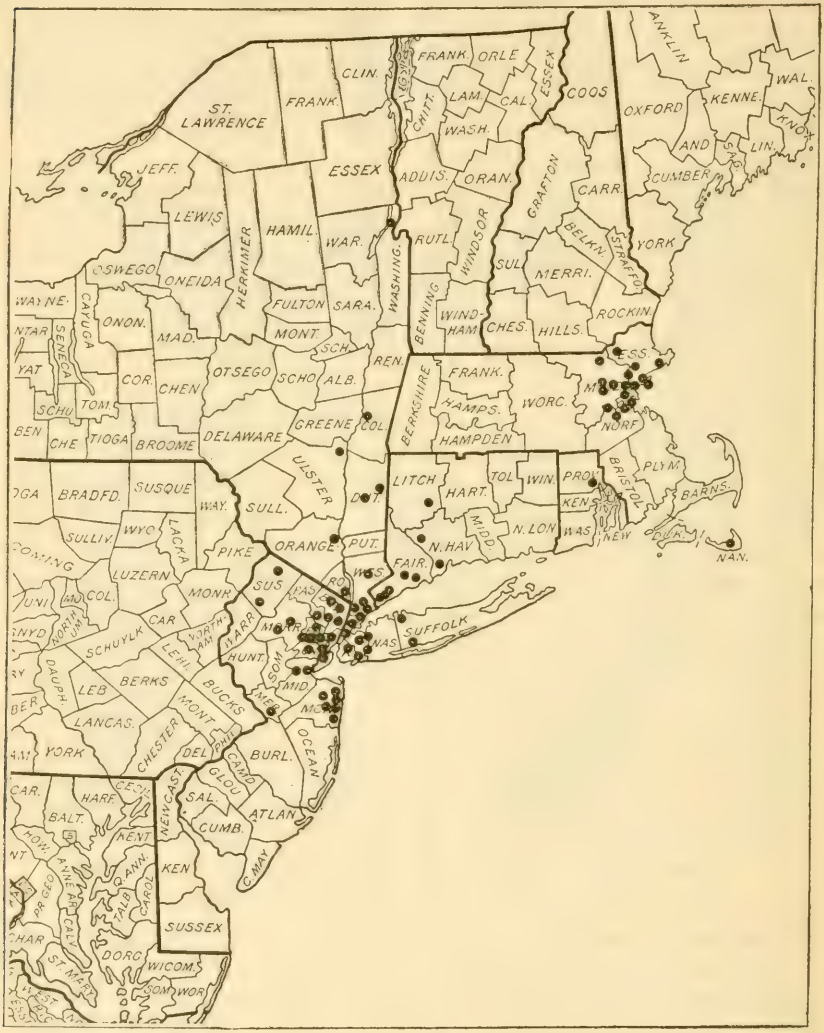

FIG. 2.—Map showing known distribution of the leopard moth in the United States in 1915. (Original.)

mined, nor has it spread to any extent from the localities which have been mentioned.

Information has been received that this species is less serious in its attacks to trees in the vicinity of New Haven, Conn., than it was six or eight years prior to the date of this publication. Taking

everything into consideration, it would seem that the species, while distributed along the coast, will, in time, be greatly reduced in this region, probably by parasites and other natural enemies, and will very gradually spread inland as it is now doing.

FOOD PLANTS.

In its Old World home the leopard moth is recorded as living on a considerable number of common trees, including elm, lime or linden, ash, beech, birch, walnut, oak, chestnut, poplar, alder, and, rarely, horse-chestnut. Among orchard trees it is reported to injure pear, apple, plum, and other fruit trees.

In the United States it attacks all of these trees and in addition practically all of the maples, ash, mountain ash, tulip tree, dogwood, aspen, and willows, such shrubs as privet and lilac, and honeysuckle. A list of 83 trees and shrubs which this larva has been actually observed to attack was compiled in 1894; 77 of these were observed in the public parks of New York City alone. A later list contains 125 species and varieties.

It will be seen by the list of food plants already presented that the number could be almost indefinitely extended, particularly in reservations like Central Park, New York City, and Prospect Park, Brooklyn, where special effort has been made to bring together a great variety of trees and shrubs. The insect will attack practically all forms of woody plants which are of suitable size for its purpose, with the exception of evergreens.

LIFE HISTORY AND HABITS.

In Europe the moths make their first appearance during July and August, but in this country they appear as early as May and continue issuing from the injured wood until late in September.

The female ready for egg laying, being particularly heavy, is unable to fly very far or very high. She deposits her eggs singly and in groups of three to four or more, and as many as 800 eggs laid by a single moth have been counted. The eggs are generally inserted in crevices in the rough bark of trees.

The larvæ hatch in about 10 days, penetrate the wood, frequently entering the nearest crotch, but also boring in at other points, and burrow tunnels into the heart or pith of twigs and the heartwood of the larger branches or trunks. When a larva has grown too large for the branch in which it is feeding it crawls out and enters a larger one. In a single tree 6 inches in diameter as many as six larvæ were observed, any one of which would have been able ultimately to destroy the tree if not removed; in fact, six to eight borers to the tree have been reported as an average in a badly infested location, and in one

instance 34 were found in a single tree. By the time the larvæ within have attained full growth, infested limbs of a certain size are likely to break off, especially during or after a severe storm, for the full-grown larva in many cases girdles the branch. The manner of girdling is shown at the top of the section of wood illustrated in figure 3. In 1893, after every storm in Central Park immense numbers of limbs were seen, some entirely broken off and others still hanging to the trees.

The larva when fully mature transforms to the pupa within its burrow, the change beginning to occur during the second May after the hatching of the eggs. The larva thus requires nearly two years to complete its growth. The pupa, by means of the sharp protuberance on its head, is enabled to force its way partly out of the burrow, after which the skin splits open and the moth emerges. The empty pupal skin remains for some time projecting from the orifice. (Fig. 1, *d*.)

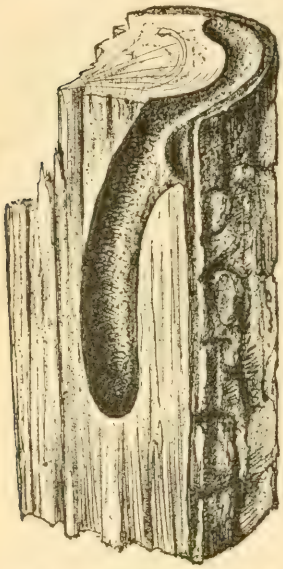

FIG. 3.—Section of wood showing burrow and girdling effect produced by larva of leopard moth. Reduced. (From Insect Life.)

The presence of this borer in a branch is manifested by an accumulation of chips, matted excrement, and frass, which indicates the entrance to the burrow. After a time these holes are closed from within by a silken web, doubtless to protect the contained insect from its natural enemies. Smaller twigs wilt and break off, and often the work of the insect is first recognized only when the severed twigs or branches have been brought down in numbers by high winds. Where the larger larvæ have worked just under the bark this splits open the next season, leaving an ugly scar as a reminder of its pernicious operations. (Fig. 4.)

NATURAL ENEMIES.

No specific natural enemies of the leopard moth other than birds appear to have been recorded in this country, although in Europe three or four wasplike parasites[1] have been reared.

In the explanation of the slow spread of the leopard moth from cities and large towns to the country, allusion has been made to the fact that native birds assist, to some extent at least, in holding

[1] An indeterminate chalcidid of the subfamily Encyrtinæ—perhaps (*Copidosoma*) *Litomastix truncatellum* Dalm.—and *Schreineria zeuzerae* Ashm., *Microgaster* sp., and one proctotrypid.

this insect in check in the suburbs. There are the best of reasons for believing that birds like the woodpeckers, which naturally look over the bark and collect all kinds of borers, prey on this species; even sparrows, it is believed, sometimes destroy the eggs and young larvæ, as they are known to devour the moths. It is also believed that when the insect succeeds in getting away from the outskirts of cities its enemies increase in number, many insectivorous birds aiding in keeping it down.

During the day the moths are fed upon by birds and later by bats and night-flying birds. The habit of the larvæ of deserting one twig and migrating to a larger one undoubtedly leaves them exposed to the same natural enemies, as this migration has been observed to take place in the daytime as well as after nightfall. It follows that the protection of native birds, especially the woodpeckers and those of related habits, will greatly assist in restraining the undue increase and spread of this borer.

Squirrels, especially the gray squirrel, which is becoming common in our large cities, have also been observed feasting on the larvæ, but neither sparrow nor squirrel should be encouraged because of this habit, since both are responsible for driving away many of our native birds.

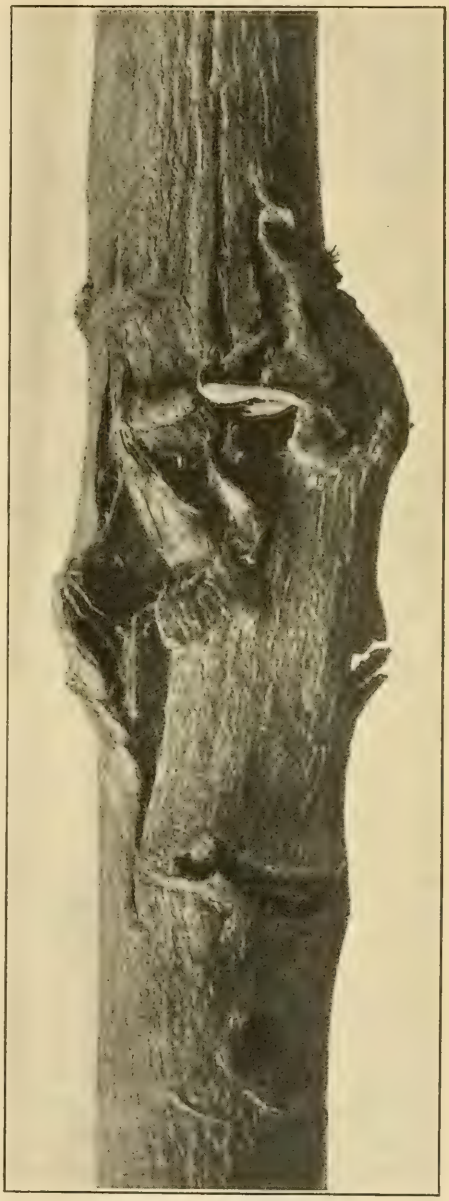

FIG. 4.—Work of the leopard moth in branch of maple. About natural size. (Original.)

METHODS OF CONTROL.

The protected and concealed manner of life of this borer, as shown by the life history, which will apply in the main to borers in general, renders it very difficult of treatment by means of insecticides or other direct measures. The most efficacious remedial measure consists in cutting off and destroying affected branches and in the injection of bisulphid of carbon into the holes or burrows where the larvæ are at work.

PRUNING AND CUTTING BACK.

Twigs or branches which, by their wilting or by the presence of burrows showing accumulations of frass or sawdust-like castings at their entrances, indicate the presence of this borer should be carefully searched out, the smaller ones pruned away and the larger ones cut back, and the amputated portions promptly burned. The stubs should be coated, preferably with grafting wax, to prevent the entrance of other insects or the spores of decay-producing fungi, although coal-tar preparations containing mineral substances are in somewhat general use for this purpose. After windstorms the affected branches which have fallen to the ground and those which remain attached to the tree should be collected and burned. Wherever trees show that they are past recovery it is best to take them out and promptly destroy them. The word "promptly" is used advisedly, since this insect, as previously stated, frequently migrates from one twig or branch to another.

INJECTING BISULPHID OF CARBON.

In the case of young and rare trees and others which show only a few larval burrows in the bark, bisulphid of carbon is the best remedy and one which has been in general use against the present species in the public parks of New York City. It is injected into the openings of the burrows, and the openings are immediately afterwards closed with various substances. For this injection a mechanic's long-spouted oil can of small size may be used on large trees, but against a related species the writers have made very good use of a small glass syringe, such as may be purchased at drug stores for about 10 cents. These glass syringes are most serviceable, because the exact amount of bisulphid may be seen when drawn into the syringe and because there is no threading to be injured by the reagent. Metal syringes may also be used, but it is more difficult to measure the exact amount, and the bisulphid acts on the leather packing. Rubber syringes are not serviceable because of rapid corrosion. About a teaspoonful of the liquid bisulphid is sufficient for each burrow.

For stopping the holes after injecting the liquid, putty and moist clay, advised by some, have been found practically useless. Grafting wax, on the other hand, gives perfect satisfaction. Coal tar is less advisable but may be substituted for the latter, or the holes may be closed by inserting a wooden plug and breaking or sawing it off even with the trunk. In any case the stopper should be tight, to exclude water from rains, which might tend to produce decomposition of the surrounding wood or invite the entrance of other insects, like carpenter and other ants and secondary borers, of which there are many species, and injurious fungi.

Carbon bisulphid should be handled with the usual precautions against fire, which means that the operator should not smoke while at work. Although the fumes should not be inhaled, as they are poisonous, the liquid will not injure ordinary trees when applied as described and does no harm to the hands.

KILLING WITH WIRES.

It is possible to reach and destroy many larvæ by forcing a copper or other pliable wire into the channels. This is a well-known borer remedy. It is impossible, however, by this means to kill the insects in all cases, owing to the length or crookedness of the burrows. Bisulphid of carbon should then be used.

ATTRACTING TO LIGHTS.

To what extent electric or other bright lights are serviceable as an agency in the destruction of the moths of this borer has not been definitely determined, but they possess a certain value. A method frequently advised consists in placing shallow pans around electric-light poles in and about parks to attract the moths. The pans are partially filled with water, and a small quantity of kerosene is poured into them. The moths flying against the globes drop into the pans and are promptly killed when they come in contact with the oil. In this way many males can be destroyed.

TREE INSPECTION.[1]

In large parks the destruction wrought by this borer annually is an important item, and it will be found profitable to establish a system of inspection consisting in the employment of park keepers

[1] During the last years of the nineteenth century a long row of beautiful red oaks bordering the street between the grounds of the Department of Agriculture and those of the Smithsonian Institution were badly infested by the related carpenter worm (*Prionoxystus robiniae* Forst.). Nearly every tree was infested, and frequently two or three burrows showed near the tops of the trunks. Bisulphid of carbon was applied, as described above, and the holes closed with grafting wax. A year later no insects could be found at work, but wherever this remedy had been applied a small scar remained. Two years later these had entirely disappeared, and the trees looked as if they had never been infested.

and boys and others who may be engaged at lower wages to keep a constant lookout for evidences of borer attack on valuable trees. In 1893 a New York entomologist spent two months in fighting this insect alone in the city parks of New York, collecting wagonloads of limbs and branches and destroying the contained larvæ and pupæ.

MAINTAINING TREES IN THRIFTY CONDITION.

If valuable trees are to be protected, the insect should not be allowed to breed in useless growth. The borers in such trees should be destroyed or the trees promptly felled and burned. Care should be exercised in transplanting trees, and fertilizers should be used in order that the trees may be always thrifty, the better to withstand attack. This also means protection from the attack of aphides, scales and defoliators such as the white-marked tussock moth and the fall webworm, and keeping them free from disease.

PROMPT AND THOROUGH TREATMENT ESSENTIAL.

Finally, in the control of this species promptness and thoroughness can not be too strongly emphasized. The bisulphid of carbon remedy should always be used where applicable, and the inspection system advised should be instituted in all public parks and on city streets infested by this pest. Individual owners of valuable trees should become acquainted with the pernicious nature of this borer, and united action should be secured with neighbors whose trees suffer from the ravages of the pest.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 721 APRIL 28, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE ROSE-CHAFER:[1] A DESTRUCTIVE GARDEN AND VINEYARD PEST.

By F. H. CHITTENDEN, *In Charge of Truck-Crop and Stored-Product Insect Investigations*, and A. L. QUAINTANCE, *In Charge of Deciduous Fruit Insect Investigations.*

CONTENTS.

INTRODUCTORY.

About the time of the blossoming of grapes, roses, and many garden flowers a long-legged beetle of a light ocher or yellowish-brown color, called the rose-chafer or "rose-bug," makes its appearance in certain sections of the country and strips bushes and vines of blossoms and foliage. This beetle is about one-third of an inch in length and may be recognized by comparison with the accompanying illustration (fig. 1, *a*).

These insects appear suddenly and in vast swarms in certain years, usually toward the middle of June in the Northern States and about two weeks earlier in their southern range, and overrun the garden, vineyard, orchard, and nursery. In about a month or six weeks from the time of their first arrival, generally after they have done a vast amount of damage, the beetles disappear as suddenly as they came.

DISTRIBUTION.

The rose-chafer occurs in the North, from Canada and Maine southward to Virginia and Tennessee, and westward to Oklahoma and Colorado. It is particularly injurious in Massachusetts, Rhode

[1] *Macrodactylus subspinosus* Fab.; order Coleoptera, family Scarabaeidae.

Island, New Jersey, Delaware, and Ohio, and has been reported as very destructive in portions of New York, Pennsylvania, Maryland, Virginia, West Virginia, Illinois, Indiana, Kansas, Nebraska, southern Michigan, and Vermont, but is not destructive in all portions of these States. Light sandy regions are greatly preferred by the insects as breeding grounds, and clay lands, unless near sandy soil, are seldom troubled with them.

FOOD PLANTS AND INJURY.

For some time after the rose-chafer was first noticed it confined its ravages to the blossoms of the rose. There is a record, however, of its having been destructive to grapes as early as 1810. In later years it has extended its range of food plants until now it is nearly

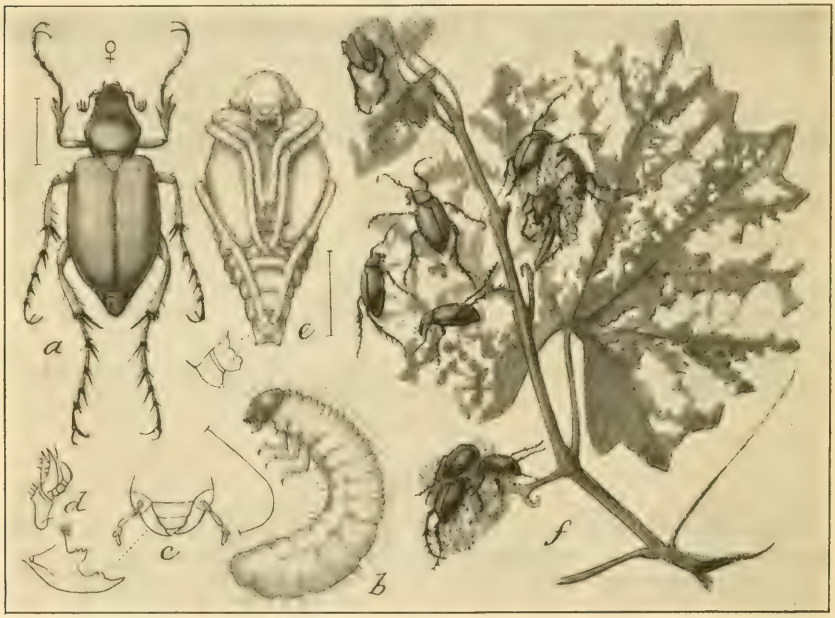

FIG. 1.—The rose-chafer (*Macrodactylus subspinosus*): *a*, Adult or beetle; *b*, larva; *c*, *d*, mouthparts of larva; *e*, pupa; *f*, injury to leaves and blossoms of grape, with beetles at work. *a*, *b*, *c*, Much enlarged; *c*, *d*, more enlarged; *f*, slightly reduced. (From Marlatt.)

omnivorous. The rose and grapevine especially suffer from its depredations, but it is almost equally destructive to fruit, shade, and other trees and shrubs. In times of great abundance these insects completely destroy flowers and other ornamental plants of many sorts, even attacking berries, peas, beans, and nearly all garden fruits and vegetables, corn, wheat, and grasses. Almost every form of vegetation is devoured.

The beetles do not confine their ravages to any particular portion of a plant, but consume alike blossoms, leaves, and fruit.

In their attack upon the grape they first devour the blossoms, then the leaves, which they completely strip, leaving only a thin network, and later the young berries are eaten (figs. 2 and 3). Whole vine-

yards and orchards are often devastated, and the fruit crop of certain sections of country destroyed. It is no uncommon sight to see every young apple on a tree completely covered and obscured from view by a sprawling, struggling mass of beetles. (See fig. 4.)

Since the late eighties the rose-chafer has been particularly injurious in grape-growing regions and has been the subject of research and experiment at the New Jersey Agricultural Experiment Station and by the Bureau of Entomology in the Lake Erie region of Pennsylvania.[1]

FIG. 2.—Grape foliage showing injury by rose-chafer. (Original.)

ROSE-CHAFER POISONOUS TO CHICKENS.

It has frequently been stated that the rose-chafer is injurious to small chickens, and it was the general belief that their death was due to mechanical injury or puncturing of the lining of the digestive tract by the spines on the legs of the beetles that had been swallowed. In other cases it was stated that the rose-chafer had eaten into the crops of the chicks. Cases have been reported recently of hundreds of chickens being killed in this manner. Death usually occurred in from 9 to 24 hours after feeding. Some experiments have been performed to determine the cause of the injury, and it was proved that

[1] Johnson, Fred. Vineyard spraying experiments against the rose-chafer in the Lake Erie Valley. U. S. Dept. Agr. Bur. Ent. Bul. 97, pt. 3, p. 53–64, pl. 4–7, fig. 16–21. 1911.

15 to 20 rose-chafers were sufficient to cause the death of a chick 1 week old. In the case of a 10-week-old chicken, 96 undigested rose-chafers were counted in a post-mortem examination. An extract made from 40 grams of rose-chafers was injected into rabbits, which died in six minutes, and in one case in three and one-fourth minutes after the injection of 4 c. c. Other rabbits were killed in proportion

FIG. 3.—Grape cluster showing almost total destruction of young berries through feeding of rose-chafer. (From Johnson.)

to the size and dose. The opinion was reached that owing to the fact that the insect feeds on a large number of plants, and especially on daisies, its body contains a neuro-toxin which affects the hearts of small animals, such as chickens and rabbits.[1]

NATURAL HISTORY AND HABITS.

The rose-chafer, as already stated, appears early in June, the date varying somewhat according to locality and season. Soon after

[1] Lamson, G. H. The poisonous effects of the rose-chafer upon chickens. *In* Science, v. 43, no. 1100, p. 138–139. Jan. 28, 1916.

emerging from the ground it mates and begins feeding. For from four to six weeks after their appearance the beetles continue feeding, almost constantly paired. The female deposits her eggs singly, from 24 to 36 in number, a few inches beneath the surface of the earth, where in from two to three weeks they hatch and the young larvæ or grubs begin feeding on such tender rootlets, preferably of grass, as are in reach. By autumn the larvæ, which are yellowish white in color, with pale-brown heads, have reached full growth and present the appearance shown in figure 1 at *b*. Late in autumn they descend

FIG. 4.—Young apple showing injury by rose-chafer. (Original.)

lower into the earth, below the frost line, each grub forming a little earthen cell in which it passes the winter. In April or early in May they transform to pupæ, and in from two to four weeks afterwards the beetles emerge, dig their way out of the ground, and renew their destructive work. A single generation of the species is produced in a year, and about three weeks is the average duration of life for an individual adult.

METHODS OF CONTROL.

The rose-chafer is one of our most difficult insect enemies to combat successfully. Almost every appropriate method that has ever been employed against other insects has been tried against this one, and much has been written on this insect, but a thoroughly effective remedy is yet to be discovered when the insects appear in excessive

numbers. Every year or two "new and successful remedies" are suggested, but when tested on a large scale in badly infested vineyards or orchards, these are found unsatisfactory.

The greatest difficulty encountered is that any application that may be made is unsuccessful unless applied almost continuously. Poisons that will kill the beetle are not satisfactory when the insects are abundant, because of their comparatively slow action. The blossoms have already been entirely destroyed before the poisons have taken effect, and the dead beetles are constantly being replaced by others that come from the ground or fly from neighboring places. Every beetle on a plant may be destroyed one day, but on the day following the plant will again be completely covered by them. Moreover, it is difficult to spray an entire garden so that every bud and blossom will be coated with the poison.

PRACTICALLY USELESS APPLICATIONS.

The various compounds of copper, lime, kerosene, and pyrethrum, hot water, and other so-called sure remedies have failed to give the desired results when subjected to a rigid test. Some substances, pyrethrum, for example, will stupefy the beetles for a short time, but they soon recover and resume feeding.

Hot water is not effective because of the practical impossibility of applying it in a spray or jet at a sufficiently high temperature to kill the insects and not destroy the fruit and flowers.

Decoctions of tobacco and quassia, as well as solutions of hellebore, alum, and a number of proprietary remedies that have been tried, apparently have no deadly effect on the rose-chafer.

USE OF ARSENICALS ON ROSES.

Paris green has not proved a success against this species, for, while it will not discolor the leaves badly, it will damage the flowers. Furthermore, repeated applications are necessary. When Paris green is added to Bordeaux mixture the combination produces bluish discolorations and seems to have little, if any, effect as a repellent. Arsenate of lead has been tried and found to be more destructive than other arsenicals, acting both as a repellent and a poison, but it works more slowly. It also has the disadvantage, in the case of ornamentals, of leaving a whitish deposit. Arsenite of zinc leaves a still thicker and a more permanent white deposit, and if fish-oil or similar soap is used as the "sticker," or adhesive, this latter substance leaves an unpleasant odor.

It is obvious, therefore, that we can not depend upon any of the arsenical group as preventives of injury by the rose-chafer to roses and other bright-flowering plants, although on some other plants they might be used successfully. Knowing these facts, it is not at all likely that the average rose grower could be induced to use any of the arsenicals.

It is possible that a heavy application of arsenate of lead, say 5 pounds to 50 gallons of either water or Bordeaux mixture, will largely protect ornamental plants that are hardy, and this plan should be tested by those who are confronted with this pest. Very thorough applications should be made on the first signs of the insects' presence and repeated as found necessary.

USE OF ARSENICALS ON GRAPES AND OTHER FRUITS.

Experiments made by the Bureau of Entomology in the grape belt of the Lake Erie Valley during 1910-11 indicate that a considerable degree of protection of vineyards from rose-chafer injury may be obtained by timely and thorough use of arsenical sprays, the amount of benefit varying with the abundance of the insects. Since the use of poison sprays at the time of rose-chafer invasion is desirable for the control of other grape pests, such as the grape berry moth, grape flea-beetle, etc., vineyards in sandy regions and subject to rose-chafer attack should be sprayed regularly for this insect as a part of the routine of vineyard work.

In the Bureau's experiments arsenate of lead has been used at the rate of 5 pounds to each 50 gallons of liquid. The poison preferably should be used in Bordeaux mixture, the application of which is essential for the control of fungous diseases. It is a prevalent belief that the addition to the poison spray of molasses or glucose renders it attractive to the beetles and insures better results. Observations and experiments on this question, while not conclusive, throw doubt on the value of the recommendation.

The first application of spray should be given just before the blossoms open, and if the beetles continue destructive the treatment should be repeated as soon as the blossoms have fallen. Arsenate of lead (paste) should be used at the rate of 4 or 5 pounds to 50 gallons of water or Bordeaux mixture, and the spray should be applied very thoroughly. Vineyardists should adopt a definite spraying schedule,[1] which will insure the maximum protection from the various insects and fungous diseases of the vine. Vineyards regularly sprayed should be less injured by the rose-chafer than those not so treated.

For the destruction of the beetles on fruit trees, as peach, apple, etc., arsenate of lead should be used, preferably in a fungicide, such as Bordeaux mixture, when the beetles first appear. It should be applied at the same strength indicated for vineyards, namely, 4 or 5 pounds to 50 gallons of spray. In spraying peaches and other stone fruits the arsenical should be used in the self-boiled lime-sulphur wash[2] or in water to which has been added lime wash made from slaking 3 or 4 pounds of good stone lime. Repeated applications may be necessary, depending upon the extent of reinfestation of the trees by newly emerged beetles, or those from other sources.

HAND PICKING.

The old-fashioned remedy of hand picking is of service when the beetles infest rose bushes, grapes, or other low-growing plants. The beetles may also be jarred from trees and bushes over sheets saturated with kerosene, but these methods are tedious and must be practiced daily in the early morning or toward sundown to be effective. A number of useful mechanical appliances formed on the plan of a funnel or inverted umbrella, with a bag or can containing kerosene at the bottom, have been devised for the collection of the beetles as they are jarred from the plants.

NETTING AND BAGGING.

Choice plants may be securely protected by a covering of netting, and when the process of bagging may profitably be employed, this method should be followed. Bagging, as is well known, prevents

[1] See Farmers' Bulletin 284, U. S. Department of Agriculture.
[2] See Farmers' Bulletin 440, U. S. Department of Agriculture.

fungous or bacterial infection, and, in addition, flowers so protected are of superior appearance and quality. Bagging of grape clusters for protection against the rose-chafer is often practiced and affords protection against other insect pests as well.

USE OF LURE PLANTS.

Small gardens may be protected, at least from the first arriving hordes of the chafers, by planting about them early-flowering plants that particularly attract the beetles. Spiræas, deutzias, andromeda, magnolias, blackberries, and white roses are especially useful as counter attractives. The beetles swarm on the flowers of these plants in preference to other flowers and small fruits, and when thus massed in great numbers their destruction by the use of collectors or other mechanical means is greatly facilitated.

DESTROYING THE LARVÆ AND PUPÆ.

In addition to the use of any of the methods described above, injury in gardens may be appreciably lessened by preventing the breeding of the insects within or in the immediate vicinity of the garden.

According to experiments conducted in Ohio during the years 1893–94,[1] the rose-chafer may be destroyed by taking advantage of the delicate nature of the pupæ. This insect while in the pupal stage is so extremely sensitive to disturbance that, even with the greatest care, specimens were not successfully transferred to the laboratory for rearing, and all specimens disturbed in their pupal cells perished. Since both larvæ and beetles are very tenacious of life, the pupal stage appears to furnish the most vulnerable period of attack, and large numbers of the pupæ may be destroyed by stirring the breeding grounds, at the appropriate time, to a depth of 3 or more inches. In the latitude of northern Ohio the most favorable time for the application of this remedy is from about May 25 to June 10. In more southern latitudes operations should be commenced earlier.

All ground which might serve as a breeding place and which it is possible so to treat should be plowed and harrowed at the proper time in the spring. The least possible area of light sandy soil should be left in sod, only the heaviest land being used for grass.

GENERAL CONSIDERATIONS.

Whatever practice of a remedial nature is undertaken, whether collecting or spraying, should be begun at the first onset of the insects' attack and continued until their disappearance. Nor should work be confined entirely to those useful plants the preservation of which is desired. Many weeds and wild plants, notably the ox-eye daisy and sumac, are special favorites of this species, and when practicable the beetles should be destroyed on them to prevent their spreading to cultivated land.

If persistent and combined effort on the part of fruit growers and truck growers of limited regions subject to infestation were made against this insect, its numbers might in a few seasons be so diminished that practical immunity from injury would be secured for several years.

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[1] Webster, F. M. The rose chafer or rose bug; how to deal with it. *In* 27th Ann. Rept. Ohio State Hort. Soc. f. 1893–94, p. 87–91. 1894.

UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 722 APRIL 21, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE LEAF BLISTER MITE OF PEAR AND APPLE.[1]

By A. L. QUAINTANCE,

In Charge of Deciduous Fruit Insect Investigations.

INTRODUCTION.

Leaf blister mites are among the smallest of animal forms which attack horticultural crops. These minute creatures, only one one-

FIG. 1.—Apple leaves injured by the leaf blister mite. (Original.)

hundred-and-fiftieth of an inch in length, are invisible to the unaided eye, and as seen under a good hand lens appear as the merest

[1] *Eriophyes pyri* Pagenstecher; order Acarina, family Eriophyidae.

speck. Although the mites themselves are probably unfamiliar to most orchardists, their work is well known to pear growers and apple growers in the reddish or greenish pimples or blisterlike spots to be noted in early spring on the young foliage of these plants. Later these blisters become brown and dead, spotting and blotching the leaves, the injury resembling that due to leaf-spot fungi or from sprays, with which injury, in fact, the work of this mite is frequently confused. When the creatures are abundant the foliage may be almost covered with the blisters or brown spots, and the usefulness of the leaves to the tree is thus greatly impaired. Foliage severely injured will fall prematurely, retarding the development of the fruit, and in extreme cases much of the crop will fall to the ground. (See fig. 1.)

The leaf blister mite is not an insect but belongs to that class of animals containing the spiders, scorpions, daddy-long-legs, etc., and to the order represented by such well-known forms as the scab mite of sheep, the cattle tick, and the red spider. Its family contains numerous species, all of which are plant feeders, attacking principally the buds and leaves. Several members of the family are of much economic importance. One[1] infests vinifera varieties of grapes in portions of Europe and in California, producing the so-called "erinose" of the vine. Another[2] is the cause of the nail-like galls sometimes found on the leaves of plum. A third[3] infests the fruit and foliage of the orange, producing a russeted condition. A fourth[4] feeds upon the upper surface of the leaves of the peach, so injuring them as to give the foliage a silvery sheen. Still another[5] occurs on the foliage of the apple, and in Montana very important injuries have been attributed to it.

ORIGIN AND DISTRIBUTION.

The leaf blister mite is not native to the United States and was probably introduced at an early period, presumably from Europe on nursery stock, buds, or scions. It was first recorded in the United States in 1872, and since that date has made its appearance in the principal pear-growing regions of the United States and Canada. It is known to occur in England, Russia, and certain other European countries, is recorded from Tasmania, and is probably present in other fruit-growing regions of the world, being at the present time a truly cosmopolitan pest.

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[1] *Eriophyes vitis* Landois.
[2] *Eriophyes padi* Nalepa (=*E. pruni-crumena* Walsh).
[3] (*Typhlodromus*) *Phyllocoptes oleivorus* Ashmead.
[4] *Phyllocoptes cornutus* Banks.
[5] *Phyllocoptes schlechtendali* Nalepa.

CHARACTER OF INJURY AND DESTRUCTIVENESS.

The mites pass the winter on the trees, under the bud scales, and attack the leaves as soon as these begin to push out in the spring. They bore small holes from the underside to the interior of the leaf, where they deposit their eggs, and with their progeny feed upon the tender cells of the leaf substance. Their activities within the leaf tissues very quickly result in the development of galls or swellings. These are at first small, pimple-like eruptions, especially evident on the upper surface of young leaves, whitish in color on the apple, but usually with a reddish tinge on the pear. The spots soon increase in size, the largest becoming as much as one-eighth of an inch in diameter. On pear leaves the spots, as a rule, become red, often brilliantly colored as they grow, whereas on apple this reddish coloring is absent or faint. On the underside of the leaf the galls are whitish and blisterlike, not differing much from the general color of the leaf surface. Later they turn brownish or black, due to the death of the injured leaf cells, lose much of their thickness, and some may become somewhat shrunken. Figure 2 illustrates a gall on pear leaf as seen in cross section, the normal structure being shown at *n*; *o* is the opening to the interior of the gall and *e* designates eggs of the mite. A cross section of one of the dried-up galls is shown in figure 3.

FIG. 2.—Pear leaf gall, in cross section, of leaf blister mite: *o*, Opening of gall; *e*, eggs of mite; *n*, normal structure of leaf. (After Sorauer.)

FIG. 3.—Section of pear leaf, showing structure of gall of blister mite in autumn; *g*, Gall; o, opening of gall. (After Comstock.)

On pear, the galls occur more along each side of the midrib of the leaf and on apple at the base of and along the margins of the leaf. When numerous, however, the spots will merge together, forming large patches or bands of variable size, often involving most of the leaf. When thus abundant the leaves may become more or less ruptured and wrinkled, and in the case of the apple the margins may curl up, showing the underside. Leaves badly infested are likely to fall prematurely, resulting also in the dropping of the fruit from clusters with worst injured foliage. The fruit and fruit-stems of

both apple and pear are also attacked, the light-colored pimples occurring mostly around the calyx end of the fruit and resulting in no material injury. The injury to the fruit-stems is noticeable as irregular thickenings, and when severe may cause some of the fruit to fall, although loss from this source, even in worst infested orchards, will not be great.

FOOD PLANTS.

Pear and apple are the more common food plants of the blister mite, though other plants are attacked. The mite has been recorded from foliage on the white beam tree,[1] the European mountain ash,[2] the wild service tree,[3] the service berry,[4] and the common cotoneaster.[5]

According to one entomologist the mites have been found on over 250 varieties of apples, injury being severe on some well-known commercial sorts, as Ben Davis, King, Baldwin, Rhode Island Greening, and at the agricultural experiment station at Geneva, N. Y., the Williams Favorite was noted to be especially subject to attack, the trees having been prematurely defoliated for two successive seasons.

DESCRIPTION AND HABITS.

The general appearance of the blister mite is shown in figure 4 in dorsal and ventral views. The mite is microscopic in size, measuring on the average about one one-hundred-and-fiftieth inch in length, whitish in color, a few individuals pinkish. The abdomen slopes gradually toward the posterior end and is numerously ringed. There are only two pairs of legs, and these and the body bear setæ which, from their character and location, are of importance in the determination of species in this group, as are also the number and character of rings on the abdomen. The young, except in size, bear a general likeness to the adults, and the eggs, though proportionately large as compared in size with the parent, are only 46 microns through the greater diameter. These are whitish, translucent, with rounded ends, and are deposited in the interior of the galls (see fig. 2). The resulting larvæ feed upon the cellular leaf substance, working out in various directions, though they are not especially active.

The mites are to be found on the foliage from their appearance in spring until fall, and several generations are evidently produced in a season. Hibernation occurs under the bud scales, the mites often congregating in colonies of 50 or more. They become active in the spring, often before the buds burst, congregating around the base of

[1] *Sorbus aria* Crantz. [2] *Sorbus aucuparia* L. [3] *Sorbus torminalis* Crantz. [4] *Amelanchier vulgaris* Moench. [5] *Cotoneaster vulgaris* Lindl.

bud scales, where they feed, many molting at this time. With the bursting of the buds and the pushing out of the tender leaves, these are attacked and the characteristic blisterlike spots soon develop.

Notwithstanding the minute size of these creatures, they fall prey in considerable number to the attack of a mite (*Seius pomi* Parrott) which is thought to assist materially in reducing their numbers.

METHODS OF CONTROL.

The leaf blister mite will yield to thorough treatment with kerosene emulsion, miscible oils, or lime-sulphur washes. The use of

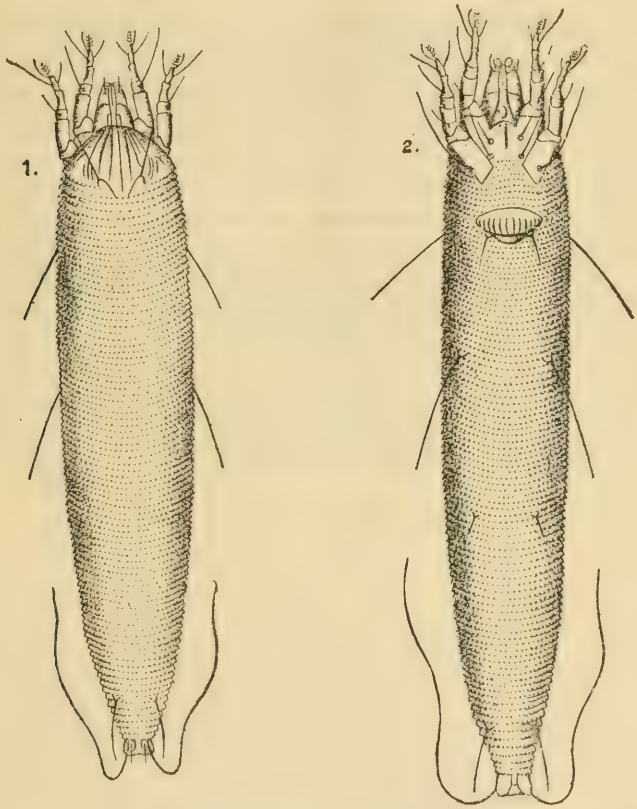

FIG. 4.—Leaf blister mite (*Eriophyes pyri*): 1, Dorsal view; 2, ventral view. Greatly enlarged. (After Nalepa.)

these sprays, as for the San Jose scale, should also protect orchards from important injury from the mites. When it is necessary to spray for the mites alone, and in cases of severe infestation, as has been noted in apple orchards in New York State, two treatments have been recommended by Parrott, standard kerosene emulsion being used, diluted with 5 parts of water. One application should be given in late fall as soon as most of the leaves have fallen and

another the following spring before the trees put out foliage. If both the fall and spring applications are not practicable, the preference should be given to fall treatment. At this time many of the mites have not yet gone to the bud scales, but occur in the pubescence of the young wood and hence are more easily killed.

Lime-sulphur washes[1] are excellent treatments for these mites and their employment is perhaps preferable as avoiding danger of injury to fruit buds by the oil sprays. If a lime-sulphur wash is employed, it should be applied with great thoroughness and the tree completely coated so that when spraying is finished it will appear as if whitewashed.

On the pear the mites may be kept reduced to an important extent simply by searching out in the spring small branches bearing worst infested leaves, pruning these off and burning them, or sprays may be employed exactly as indicated for the apple, if this is considered necessary.

Except in cases of serious infestation special spraying for the blister mite will not be necessary. As to whether or not it is advisable to spray, the orchardists will have to decide after determining as exactly as is possible the amount of injury that is being done by the mites, and care should be taken not to confound with its injury that which has resulted from fungicidal or Paris-green sprays, and from leaf-spot diseases.

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[1] Information concerning the preparation of lime-sulphur washes and kerosene emulsion will be found in Farmers' Bulletin 650, U. S. Department of Agriculture, pp. 16–25.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 723 APRIL 26, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE OYSTER-SHELL SCALE[1] AND THE SCURFY SCALE.[2]

By A. L. QUAINTANCE, *In Charge of Deciduous Fruit Insect Investigations*, and E. R. SASSCER, *Collaborator*.

CONTENTS.

INTRODUCTION.

The oyster-shell scale [1] and the scurfy scale [2] are, with the exception of the San Jose or Chinese scale,[3] more frequently the subject of

FIG. 1.—Oyster-shell scale (*Lepidosaphes ulmi*) on poplar. Much enlarged. (Authors' illustration.)

inquiry by orchardists than all other species of scale insects combined. These two scale pests are now very generally distributed

[1] *Lepidosaphes ulmi* L. [2] *Chionaspis furfura* Fitch. [3] *Aspidiotus perniciosus* Comst.

throughout the country, and from their relatively conspicuous appearance are often detected by observant fruit growers who frequently believe them to be the more serious San Jose scale. The oyster-shell and scurfy scales, while not dangerous in the sense of generally causing the death of infested trees, are, however, of considerable economic importance. The complete killing of individual branches of apple trees by either species is a matter of frequent observation, and trees so badly infested are frequently greatly stunted and retarded in their growth, resulting perhaps in extreme cases in the death of the trees. Of the two species considered, the oyster-shell scale has been and is at the present time the more important. Its injuries to certain shade trees, especially poplar and maple, have been the cause of much complaint during recent years. Such shade trees are ordinarily not sprayed for scale insects, and the increase of these pests from year to year is thus checked only by their natural enemies. The writers have frequently seen maple and poplar trees literally incrusted from top to bottom with the oyster-shell scale, many of the limbs killed, and in rarer instances the trees quite dead, without doubt owing to the attack of this scale insect.

THE OYSTER-SHELL SCALE.

ORIGIN AND DISTRIBUTION.

The origin of the oyster-shell scale is a matter of some uncertainty. It has a world-wide distribution, and was introduced into the New England colonies at an early date. The first American account of this insect was written by Enoch Perley in 1794, and in it he stated that the pest was doing considerable damage to the apple in Cumberland County, Me. Shortly after 1860 it had reached the Mississippi River, and at the present time occurs in every State of the Union with the possible exception of South Dakota, Oklahoma, and Texas. Its occurrence in these States is practically certain, but there appear to be no records in literature to this effect, and it has not been received from these States by the Bureau of Entomology. The insect is very troublesome in the Northern States and is especially common in the New England States and those bordering the Great Lakes.

DESCRIPTION AND LIFE HISTORY.

This insect has received the common name "oyster-shell scale," owing to the resemblance of its scale, or covering, to a long narrow oyster shell, as may be seen by reference to figures 1 and 2. The adult female scales are about one-eighth of an inch in length, usually brown to dark brown in color, though occasionally they have a grayish appearance which is due to bleaching over winter. If present in large numbers, for want of room they assume various more or less

curved shapes. The scale of the male in shape and color resembles that of the female, but is smaller and possesses at the posterior extremity a small hinge or flap which permits the exit of the adult male.

If during winter or early spring one of the female scales be removed, numerous small, oval, white eggs varying in number from 40 to 100 will be revealed, and at the anterior portion can be seen the dead and shriveled body of the female.

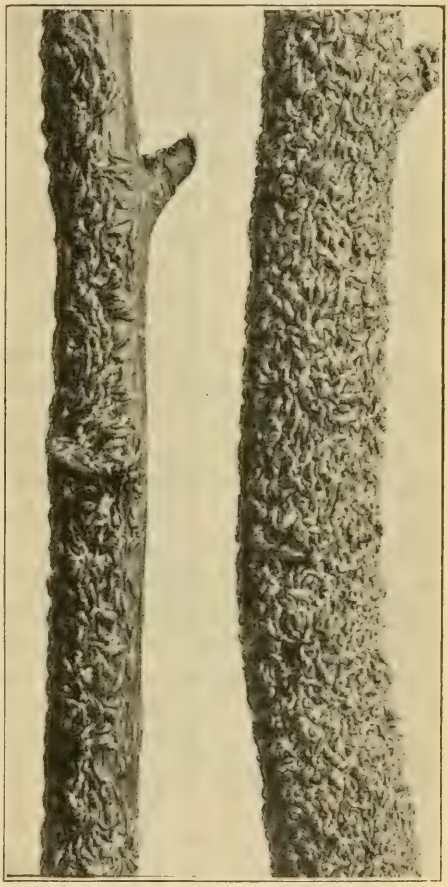

FIG. 2.—The oyster-shell scale (*Lepidosaphes ulmi*). Enlarged. (Authors' illustration.)

In Canada and the Northern States there is thought to be but one full brood annually, whereas in the Middle and Southern States the species is double brooded.

The following records from literature and from the Bureau of Entomology will indicate the time in the spring of hatching of the eggs of this insect, in various localities. This time will of course vary with the season, but in general, as long ago stated by Dr. Mygatt in Illinois, will for any locality be shortly after the time of the falling of the blossoms of the apple.

Ontario: Eggs hatch about first week of June (Jarvis).

New York: Eggs hatch latter part of May to early June (Felt).

New Hampshire: Eggs hatch in late May to early June (Sanderson).

Vermont: Eggs hatch in late June (Stewart).

Maine: Eggs hatch about middle of June or later, depending upon the season (Hitchings).

Michigan: In specimens received June 18, 1909, from Stittsville, Mich., nearly all eggs had hatched (Sasscer).

Minnesota: In specimens received May 24, 1909, from Lamoille, Minn., eggs were hatching in numbers when received (Sasscer).

Indiana: In specimens received from Elwood, May 14, 1909, eggs were hatching in numbers when received (Sasscer).

Ohio: Eggs hatch in late May to early June (Gossard).

Second-brood eggs were found under many scales August 22, and a few young crawling at Cleveland (Quaintance).

West Virginia: In specimens received April 30, 1908, from Parkersburg, W. Va., young were crawling in numbers (Sasscer).

Missouri (Wright County): Eggs hatch early in May. Insect double brooded according to a Mr. Wright (Riley).

Olden, Mo., eggs hatched March 29, 1907; apple trees bloomed March 24 (Girault).

Ozark region, Missouri, eggs hatch about April 25 to middle of May (Taylor).

Illinois (Cook County): Eggs hatch about June 6, females reach full growth by August 1, and oviposit August 12–28 (Riley).

District of Columbia: Eggs hatch May 5–14 (Quaintance).

July 4, eggs already deposited by most females and young crawling (Quaintance).

Maryland: Eggs hatch early in May (Symons).

Eggs of first brood hatch in May; eggs of second brood hatch in last week of July to first week of August (Johnson).

College Park, many recently settled scales in evidence May 21 (S. W. Foster).

Delaware: Eggs usually hatch in early May (Houghton).

New Jersey: Eggs hatch during early June (Smith).

Tennessee: In eastern Tennessee eggs hatch during first two weeks of April (Chambliss).

Eggs begin to hatch in April and those of the second brood along in July and August (Bentley).

This information as to the period of hatching of eggs in various parts of the country is of importance as bearing on the time to spray for the destruction of the young larvæ.

The female molts twice in the course of her growth, and in the adult condition is entirely without legs or eyes, being nothing more than a reproductive sack with her sucking mouth parts, through which the food is taken, inserted in the tissues of the plant. The adult male differs radically from the female in that it is provided with antennæ and one pair of wings, the second pair being present in the form of club-shaped organs known as balancers or halteres. During the process of change the mouth parts entirely disappear, and a second pair of rudimentary eyes assumes their place. Being without any means of taking in food, the male is naturally very short lived, its only mission appearing to be the fertilization of the female.

MEANS OF DISTRIBUTION.

Transportation by nursery stock, scions, or grafting or budding material is perhaps the only way this insect is carried from one section of the country to another, and this in a large measure accounts for its wide distribution. Locally it can be transferred from plant to plant only while in the young or crawling stage. The young are often seen crawling on other insects, such as beetles, or upon the feet of birds, and may in this way be carried some distance. Man and domestic animals may also assist in their dissemination, and it is possible that the winds blow them from plant to plant.

FOOD PLANTS.

The oyster-shell scale has a wide range of food plants, but is commonly found on apple, maple, horse-chestnut, poplar, willow, and lilac. The following is a list of the plants on which it is known to occur throughout the world:

Alder (*Alnus rugosa* Spreng.).
Almond (*Prunus* sp.), China.
American aspen (*Populus tremuloides* Michx.).
American bladdernut (*Staphylea trifolia* Linn.).
Amorpha sp.
Andromeda sp.
Apple (*Malus sylvestris* Miller).
Apple, crab (*Malus* sp.).
Apricot (*Prunus armeniaca* Linn.).
Arrow-wood (*Viburnum* spp.).
Ash (*Fraxinus americana* Linn.), (*F. excelsior* Linn.), (*Fraxinus* spp.).
Barberry (*Berberis* sp.).
Balm of Gilead (*Populus balsamifera* Linn.).
Basswood (*Tilia americana* Linn.), (*T. angustifolia*).
Beech (*Fagus atropunicea* Sudw.).
Bilberry (*Vaccinium myrtillus* Linn.).
Birch, white (*Betula populifolia* Ait.).
Birch, river (*Betula nigra* Linn.).
Bittersweet (*Celastrus scandens* L.).
Blackthorn (*Prunus spinosa* Linn.).
Blueberry (*Oxycoccus* sp.).
Box (*Buxus sempervirens* Linn.).
Boxelder (*Acer negundo* Linn.).
Broom (*Cytisus scoparius* Link.), Gurnsey. (*C. nubigensus* Link.), from Gurnsey (?).
Buckeye (*Aesculus glabra* Wild.).
Buckthorn (*Rhamnus cathartica* Linn.).
Butternut (*Juglans cinerea* Linn.).
Calluna sp.
Camellia sp.
Camphor tree (*Cinnamomum camphora* (L.) Nees & Eberm.).
Cassia sp., in greenhouse.
Cherry (*Prunus* sp.).
Chestnut (*Castanea americana* Raf.).
Clematis paniculata Thunb.
Cocoa palm (*Cocos nucifera* L.).
Cotoneaster sp.
Cranberry (*Oxycoccus* sp.).
Currant, black (*Ribes nigrum* Linn.).
Currant, mountain (*Ribes alpinum*).
Currant, red (*Ribes rubrum* Linn.).
Dogwood (*Cornus alba* Linn.), (*C. alba* var. *sibirica*. Lodd.), (?*C. alterna* Marsh), (*C. californica* C. A. Mey), (*C. sanguinea* Linn.).
Elm, English (*Ulmus campestris* Smith).
Elm, purple-leaved (*Ulmus scabra* var. *purpurea* Koch).
?*Euphorbia palustris* Linn., Germany.
False bittersweet (*Celastrus scandens* Linn.).
Fig (*Ficus carica* Linn.).
Filbert (*Corylus* sp.).
Ginseng (*Panax quinquefolium* Linn.).
Gooseberry (*Ribes cynosbati* Linn.).
Goatsbeard (*Aruncus sylvester* Kost.).
Grape (*Vitis vinifera* Linn.).
Hackberry (*Celtis occidentalis* Linn.).
Hawthorn (*Crataegus crus-galli* Linn.), (*C. oxyacantha* Linn.).
Helianthemum chamaecistus Mill., England.
Heath (*Erica* sp.), England and Sweden.
Heather (*Calluna* sp.).
Holly (*Ilex crenata* Thunb.).
Honeysuckle (*Lonicera* sp.).
Hop tree (*Ptelea trifoliata* Linn.).
Horse-chestnut (*Aesculus hippocastanum* Linn.).
Hovenia inaequalis.
June-berry (*Amelanchier* spp.).
Leather leaf (*Chamaedaphne calyculata* Moench).
Lilac (*Syringa persica* Linn.), (*S. vulgaris* Linn.).
Lime (*Citrus* sp.).
Linden. (*See* Basswood.)
Locust, cultivated (*Robinia pseudacacia* Linn.).
Locust, water (*Gleditsia aquatica* Marsh).
Maple, red (*Acer rubrum*).
Maple, striped (*Acer pennsylvanicum* Linn.).
Maple, sugar (*Acer saccharum* Marsh).
Maple, mountain (*Acer spicatum* Lam.).
Mespilus cuneata Miq.
Moose-wood (*Dirca palustris* Linn.).
Mountain ash (*Sorbus americana* Marsh).

Mountain ash, European (*Sorbus aucuparia* Linn.).
Myrtle (*Myrtus* sp.).
Nectarine (*Amygdalus persica nectarina* Ait.).
New Jersey tea (*Ceanothus americanus* Linn.).
Oak (*Quercus pedunculata* Ehrh.), (*Quercus* spp.).
Orchid.
Pachysandra terminalis Sieb. & Zucc.
Peach (*Amygdalus persica* L.).
Pear (*Pyrus communis* Linn.).
Pear, Seckel.
Peony (*Paeonia* sp.).
Peppergrass (*Lepidium suffruticosum* Linn., Cav.).
Planera keakei C. Koch.
Plum (*Prunus domestica* Linn.).
Poplar, Carolina (*Populus deltoides*).
Poplar, Lombardy (*Populus nigra* var. *italica* Du Roi).
Poplar, white (*Populus alba* Linn.).
Prunus sargentii.
Quince (*Cydonia vulgaris* Pers.).
Raisin tree (*Hovenia dulcis*).
Raspberry (*Rubus* spp.).
Rhamnus sp.
Rose (*Rosa rugosa* Thunb.).
Sassafras (*Sassafras sassafras* Karst.).
Silverberry (*Elaeagnus argentea* Pursh.).
Spiraea spp.
Spruce (*Abies firma* Sieb. & Zucc.).
Sunflower (*Helianthus* sp.).
Sycamore (*Platanus* sp.).
Tallow tree (*Sapium sebiferum* Roxb.).
Tamarisk (*Tamarix africana* Poir.).
Tree of Heaven (*Ailanthus cacodendron* [Ehrh.] Schinz. & Thell.).
Tulip-tree (*Liriodendron tulipifera* Linn.).
Umbrella tree (*Magnolia tripetala* Linn.).
Viburnum sp.
Virginia creeper (*Ampelopsis quinquefolia* Michx.).
Willow, goat (*Salix caprea* Linn.).
Willow, Napoleon (*Salix babylonica* Linn.).
Willow, osier (*Salix viminalis* Linn.).
Willow (*Salix aegyptiaca* Forsk.).
Willow (*Salix pedicellata* Desf.).
Walnut, English (*Juglans regia* Linn.).
Walnut (*Juglans* sp.).
Yucca (*Yucca* sp.).

PARASITIC AND PREDACEOUS ENEMIES.

Minute parasitic wasps are often efficient enemies of this scale, and in some localities they apparently hold the insect in check. If these little friends [1] are present, small round holes can be seen on the dorsal part of the scale showing where the adult escaped.

The larvæ of coccinellids, or ladybeetles, are sometimes found feeding on these insects, and certain species of mites assist in their destruction. Birds are also credited with doing service, the most efficient being the titmice and tree creepers.

THE SCURFY SCALE.

The scurfy scale, while infesting a considerable number of plants, is a less general feeder than is the preceding species. It occurs principally upon rosaceous plants, such as the apple, peach, pear, plum, cherry, etc., and also on currant and gooseberry among cultivated plants, but seldom becomes so abundant as to cause particular injury or to require specific treatment. The insect may be recognized from the accompanying illustration (fig. 3), much enlarged. The scale of the female is dirty gray in color, irregularly pear-shaped, as shown in the picture. The male scales are much smaller, elongate, snowy white,

[1] Those more commonly found are *Aphelinus mytilaspidis* Le B., *A. abnormis* How., *A. fuscipennis* How., *A. diaspidis* How., *Aspidiotiphagus citrinus* How., *Anaphes gracilis* How., and *Cheiloneurus diaspidinarum* How.

with three distinct keels extending longitudinally along the back. Unlike the former species, the scurfy scale is a native North American insect, and appears to be less adaptable to the various conditions throughout the country, and has thus a more restricted distribution.

LIFE HISTORY AND HABITS.

The scurfy scale, like the oyster-shell scale, winters in the egg condition under the scales. The number which may be deposited by a

FIG. 3.—The scurfy scale (*Chionaspis furfura*). Male at right, female at left. All enlarged. (Authors' illustration.)

given female, as may be easily verified by examination, varies considerably. The following records show the number of eggs from each of twenty individuals:

Number of eggs deposited by the scurfy scale. (Material collected on apple sprouts from base of apple stump March 31, 1905, at Arlington Farm, Virginia.)

Scale No.	Eggs.	Scale No.	Eggs.	Scale No.	Eggs.	Scale No.	Eggs.
1	61	6	74	11	54	16	82
2	18	7	78	12	61	17	23
3	78	8	70	13	48	18	83
4	98	9	19	14	68	19	21
5	53	10	41	15	78	20	33

Average number of eggs per scale, 57.5.

The following records from literature and from the Bureau of Entomology will indicate the times of hatching of the eggs of this insect in the spring for several localities:

Ontario: Eggs hatch about June 1 (Jarvis).

Connecticut: Eggs hatch usually between May 20 and June 1 (Britton).

New York: Eggs hatch at about same time as those of oyster-shell scale.

Ohio: Eggs hatch, and young are crawling, during latter part of May or in early June (Houser).

Illinois: Eggs hatch from June 5 to 12 (Walsh).

Missouri: Eggs hatch soon after the formation of the young apples, the date depending upon locality and upon forwardness of the spring (Taylor).

District of Columbia: Eggs hatch from May 15 to June 1 (Howard).

Delaware: Eggs hatch about same time as those of oyster-shell scale, which is usually early in May (Houghton).

Tennessee: Eggs hatch in April, and there are two broods annually (Bentley).

Georgia: In 1906 eggs hatched March 11 to 22. Eggs for second brood hatched beginning about June 2.

In the more northern States there is but one brood each year, but in the South, as in Tennessee and in Georgia, there are evidently two full broods, and in the latter State there is a strong probability of a third. Thus, at Myrtle, Ga., in 1906, the eggs were hatching March 11, and hatching had probably ceased by March 22. Males of the new brood appeared May 15, and eggs had been deposited by the female May 28, the hatching beginning June 2.

DISTRIBUTION.

The following records of distribution have been compiled from various publications and from data collected by the Bureau of Entomology:

California, Colorado, Connecticut, Delaware, District of Columbia, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Utah, Virginia, Washington, West Virginia, and Wisconsin. In Canada it is recorded from New Brunswick, Nova Scotia, Ontario, and Prince Edward Island.

FOOD PLANTS.

The list which follows includes all plants upon which this species has been found, so far as it has been possible to determine from records in literature and from those in the Bureau of Entomology.

Apple (*Malus sylvestris* Miller).

Apple, Chinese flowering (*Malus spectabilis* Ait.).

Apple, crab (*Malus* sp.).

Ash, European mountain (*Sorbus aucuparia* Linn.).

Ash, mountain (*Sorbus americana* Ait.).

Ash, prickly (*Xanthoxylon americanum* Mill.).

Ash, white (*Fraxinus americana* Linn.).

Aspen, largetooth (*Populus grandidentata* Michx.).

Buckthorn (*Rhamnus cathartica* Linn.).
Cherry, choke (*Prunus virginiana* Linn.).
Cherry, wild black (*Prunus serotina* Ehrh.).
Cherry, wild red (*Prunus pennsylvanica* Linn.).
Chokeberry, black (*Aronia melanocarpa* [Michx.] Elliott.
Chokeberry, red (*Aronia arbutifolia* [L.] Pers.
"Cherry currant."
Cotton (*Gossypium* sp.).
Currant, black (*Ribes nigrum*).
Currant, red flowered (*Ribes sanguineum* Pursh.), England.
Elm(*Ulmus* sp.).
Gooseberry (*Ribes* sp.).
Hawthorn (*Crataegus oxyacantha* Linn.).
Hickory, big bud (*Hicoria alba* Britt.).
Horse chestnut (*Aesculus hippocastanum* Linn.).
Maple (*Acer* sp.).
Peach (*Amygdalus persica* L.).
Pear (*Pyrus communis* Linn.), (*P. heterophylla* Dur.) (*P. melanocarpa*).
Plum, purple-leaved (*Prunus pissardii* Hort.).
Plum, common garden (*Prunus domestica* Linn.).
Quince (*Cydonia vulgaris* Pers.).
Quince, Japan (*Chaenomeles japonica* [Thunb.] Lindl.).
Raspberry, black cap (*Rubus occidentalis* Pers.).
Red-twigged dogwood (doubtful record).
Shad-bush (*Amelanchier canadensis* Medic.).
Sweet gum (*Liquidambar styraciflua*).
Sweet pepper bush (*Clethra alnifolia* Linn.).
Walnut, black (*Juglans nigra* Linn.).
Willow, white (*Salix alba* Linn.).

The scurfy scale is especially common on apple and pear, less usually so on cherry and peach, on which latter host in the South, in certain cases which have come under the writers' observations, it proved very destructive, greatly stunting the trees, although none had actually been killed.

PARASITIC AND PREDACEOUS ENEMIES.

This species is apparently not so subject to attack of parasitic and predaceous insects as the preceding, or else attention has not been directed to this phase of the insect's economy to an equal extent.[1]

METHODS OF CONTROL FOR BOTH SPECIES.

Preparatory to spraying orchard, shade, and ornamental trees and plants for scale insects, they should be carefully gone over and any dead and weakened parts pruned out. The presence of such dead and dying wood is a distinct detriment, and its removal will greatly simplify the work of spraying.

TREATMENT OF ORCHARDS.

In orchards well sprayed during the dormant period for the San Jose scale each year, the oyster-shell and scurfy scales should rarely prove troublesome. While these insects, by reason of their wintering in the egg stage under the protecting female scales, are less susceptible to washes effective against the San Jose scale, yet the treatments will in most cases keep them reduced below injurious numbers.

[1] The following predaceous species are recorded as feeding upon the scurfy scale: *Tyroglyphus malus* (Shimer), *Chilocorus bivulnerus* Muls., and *Hyperaspidius* sp.

Among the parasitic Hymenoptera *Ablerus cliziocampae* (Ashm.) has been reared from this species as well as *Physcus varicornis* How., and a species of the genus Prospaltella.

In orchards where spraying for the San Jose scale is unnecessary and where the oyster-shell and scurfy scales are troublesome, specific treatments become desirable. There is considerable difference of opinion among entomologists as to the effectiveness of sprays applied during the dormant season to effect the destruction of the eggs. There is greater uniformity of opinion, however, as to the effectiveness of spraying shortly after the young have hatched and before there has been time for the formation of a thick protecting scale.

Recent observations and experiments, especially those by Messrs. E. W. Scott and W. S. Abbott in connection with the enforcement of the Insecticide Act of 1910, indicate that lime-sulphur wash is adequately effective against the oyster-shell scale applied during the dormant season, exactly as is done for the control of the San Jose scale. The lime-sulphur wash appears to seal the eggs and young under the scale covering, and probably also acts as a deterrent to the settling of the young lice on the twigs and branches. The effectiveness of such treatments, however, would probably vary with weather conditions which would tend to interfere with the "sealing" action of the wash. It is recommended, therefore, that orchardists use for the control of the oyster-shell and scurfy scales the lime-sulphur wash now in general use against the San Jose scale. A single dormant-tree treatment should be effective in controlling these three scale insect pests. It is essential, however, that very thorough applications be made, and in the case of large apple trees with a good deal of rough bark on the limbs and branches, this should be scraped off where practicable, since many of the scale insects will find protection under the loose pieces of bark.

If for any reason the dormant-tree treatment has not been satisfactory, as shown by the abundance of young scales hatching in the spring, an additional spraying, using kerosene emulsion or fish-oil soap wash, may be desirable, directed against the "lice" just hatched. The records of dates of hatching given under the remarks on life history for each species will indicate approximately when the young insects may be expected to appear, but this time may be accurately determined by frequent examinations of infested trees. The very small, yellowish insects will be seen in numbers crawling over the limbs and branches in their efforts to find a suitable place for settling. In general, the young of both species will have hatched and settled, and may be effectively treated during the period of from one to three weeks following the blooming period of the apple, and from two to four weeks after the blooming period of the peach. It will be preferable, however, to determine positively the time of crawling of the young for the particular locality and food plant by actual observations.

In spraying for the young insects when the trees are in foliage, the presence of the foliage will render thorough work more difficult, and special care will be necessary to reach all limbs and branches, treating every portion of the tree from top to bottom, as only those insects actually hit are destroyed. Dilute lime-sulphur wash, as used for fungicidal purposes, while of considerable value in destroying the newly hatched insects, is not as effective as kerosene emulsion or fish-oil soap wash, later mentioned under the head of formulas.

TREATMENT OF SHADE TREES.

The oyster-shell scale will often require treatment on maples, Lombardy and Carolina poplars, ash, and willow. Such trees should be sprayed with the strong lime-sulphur wash during the dormant period as advised for fruit trees, and if the insects have not been satisfactorily controlled, a supplemental treatment with kerosene emulsion or fish-oil soap wash should be made as the young are hatching. Effective spraying of shade trees, where these are of some size, will require painstaking work. In many cases it will be necessary for the man handling the nozzle to climb into the trees to reach the higher limbs and branches, and a long extension or bamboo rod is indispensable. The length of hose must be adapted to the height of the trees to be treated, and a coarse nozzle will be preferable, since it enables the operator to throw the spray some distance to inaccessible branches. A high pressure pump, from 150 to 200 pounds, is essential, though the writers have seen good work accomplished with an ordinary barrel outfit.

TREATMENT OF CURRANTS, GOOSEBERRIES, ORNAMENTAL SHRUBS, AND OTHER LOW-GROWING PLANTS.

After proper pruning, shrubs and bushes infested with these two scale pests should be thoroughly sprayed during the dormant period with the strong lime-sulphur wash as indicated for orchard and shade trees. If desirable, a supplemental treatment may be made as the young are hatching, as already indicated. A knapsack or bucket pump will be suitable for treating a few plants in yards, though if the amount of spraying to be done is considerable, a barrel pump would be preferable. Where infested yard plants are growing close to the wall of the building, this may be protected during the operation of spraying by a piece of tarpaulin, or other heavy cloth, or even waste paper.

SPRAY FORMULAS.

KEROSENE EMULSION (STOCK SOLUTION, 66 PER CENT OIL).

Kerosene emulsion is made after the following formula:

Kerosene (coal oil, lamp oil)	gallons	2
Fish oil or laundry soap (or 1 quart soft soap)	pound	½
Water	gallon	1

First dissolve the soap in boiling water; then remove the vessel from the fire. Immediately add the kerosene, and thoroughly agitate the mixture until a creamy solution results. The stock emulsion may be more conveniently made by pouring the mixture into the tank of a spray pump, and pumping the liquid through the nozzle back into the tank for some minutes. The stock solution, if well made, will keep for some months, and is to be diluted before use. To make a 10 per cent spray (the strength for trees in foliage) add to each 1 gallon of the stock solution about $5\frac{2}{3}$ gallons of water. For 20 and 25 per cent emulsions (for use on dormant trees and plants) use respectively about $2\frac{1}{3}$ and $1\frac{2}{3}$ gallons of water for each 1 gallon of stock emulsion. Agitate the mixture in all cases, after adding the water. The preparation of the emulsion will be simplified by the use of a naphtha soap. No heat will be required, as the kerosene will combine readily with the naphtha soap, in water, when thoroughly agitated. Double the quantity of naphtha soap given in the above formula, however, will be required, and soft or rain water should be used in making the emulsion. In regions where the water is "hard" this should first be broken with a little caustic potash or soda, as common lye, before use for dilution, to prevent the soap from combining with the lime or magnesia present, thus liberating some of the kerosene, or rain water may be employed.

CRUDE PETROLEUM EMULSION.

Crude petroleum emulsion may be prepared in identically the same way as has just been described for kerosene emulsion, crude petroleum being substituted for kerosene. The grade of crude petroleum employed in the East is that known as "insecticide oil," having a specific gravity of 43° to 45° Baumé. The same dilutions for winter and summer spraying should be observed as stated for kerosene emulsion, but it should be noted that for summer treatments of trees in foliage the kerosene emulsion is preferable, as it is less likely to cause injury.

FISH-OIL SOAP WASH.

There are several brands of fish-oil soap on the market. Potash soap is preferable, and it should not contain over 30 per cent of water. For spraying dormant trees the soap is dissolved in hot water at the rate of 2 pounds to each 1 gallon, and spraying should be done before the wash cools, otherwise it is forced through the nozzle with difficulty. For spraying trees in foliage use the soap at the rate of 1 pound to 3 or 4 gallons of water, or even weaker.

LIME-SULPHUR WASH.

A good lime-sulphur wash may be made for immediate use by the following formula:

Stone lime	pounds	20
Sulphur (flour or flowers)	do	15
Water to make	gallons	50

Heat in a cooking barrel or vessel about one-third of the total quantity of water required. When the water is hot add all the lime and at once add all the sulphur, which previously should have been made into a thick paste with water. After the lime has slaked, about another third of the water should be added, preferably hot, and the cooking should be continued for one hour, when the final dilution may be made, using either hot or cold water, as is most convenient. The boiling due to the slaking of the lime thoroughly mixes the ingredients at the start, but subsequent stirring is necessary if the wash is cooked by direct heat in kettles. If cooked by steam, no stirring will be necessary. After the wash has been prepared it must be well strained as it is being run into the spray tank. It may be cooked in large kettles, or preferably by steam in barrels or tanks. This wash should be applied promptly after preparation, since, as made by this formula, there is crystallization of the sulphur and hardening of the sediment upon cooling. While an excess of lime, as in the above formula, adds nothing to the effectiveness of the wash, it serves by its color to indicate how thoroughly the trees are being coated. Another formula, with just sufficient lime for union with the sulphur, is employed by many orchardists in the preparation of the wash for immediate use as follows:

Stone lime	pounds	7½
Sulphur (flowers or flour)	do	15
Water to make	gallons	50

This is prepared as already indicated. While this wash may be stored without injury, it is better to prepare the "concentrate," as later described, if it is to be stored.

COMMERCIAL LIME-SULPHUR CONCENTRATES.

The inconvenience experienced in preparing the lime-sulphur wash according to the foregoing formula by cooking with steam or in open kettles at home has been one of the principal objections to this spray. Manufacturers have, therefore, put on the market concentrated solutions of lime-sulphur which have only to be diluted with water for use. These commercial washes, if used at proper strength, have proved to be quite as satisfactory in controlling the scale as the old-formula lime-sulphur wash, and, although somewhat more expensive, have been adopted by many of the commercial orchardists in prefer-

ence to making the wash at home. They are especially useful for the smaller orchardists whose interests do not warrant the construction of a cooking plant.

HOMEMADE LIME-SULPHUR CONCENTRATES.

The question of the preparation at home of concentrated lime-sulphur solutions which will not crystallize upon cooling, thus duplicating the commercial product, has been investigated by the Bureau of Entomology, as well as by numerous experiment station entomologists, notably by Profs. Stewart, Cordley, Parrott, and others. It has been demonstrated that it is practicable for orchardists to prepare concentrated stock solutions of lime-sulphur wash for immediate or later use, and many orchardists employ this plan. The necessary details for the preparation at home of lime-sulphur concentrates are given in Farmers' Bulletin 650 of this department. Those interested in the preparation for storage of lime-sulphur concentrate should write for this publication.

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Danger of General Spread of the Gipsy and Brown-tail Moths Through Imported Nursery Stock. (Farmers' Bulletin 453.)
The More Important Insect and Fungous Enemies of the Fruit and Foliage of the Apple. (Farmers' Bulletin 492.)
The Gipsy Moth and the Brown-tail Moth, with Suggestions for Their Control. (Farmers' Bulletin 564.)
The San Jose Scale and Its Control. (Farmers' Bulletin 650.)
The Apple-Tree Tent Caterpillar. (Farmers' Bulletin 662.)
The Round-headed Apple-tree Borer. (Farmers' Bulletin 675.)
Grape Leafhopper in Lake Erie Valley. (Department Bulletin 19.)
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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 725 APRIL 29, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

WIREWORMS DESTRUCTIVE TO CEREAL AND FORAGE CROPS.

By J. A. HYSLOP, *Entomological Assistant, Cereal and Forage Insect Investigations.*

CONTENTS.

INTRODUCTION.

The purpose of this bulletin is to enable farmers to distinguish between the different kinds of wireworms, so that they can make use of the method shown to be best in the control of each. It is apparent from several years of investigations into the habits and life histories of wireworms that many of the so-called wireworm remedies are of little or no value. Wireworms occur practically everywhere and attack a great variety of crops, and the character of the damage produced is similar in most cases and usually necessitates a reseeding or replanting.

The species here treated are the wheat wireworm [1] of the Northeastern and Middle Western States, the corn wireworms [2] of the Middle Atlantic and New England States and the Mississippi Valley, the meadow wireworms (including the sugar-beet wireworm [3] and the confused wireworm [4]), the corn and cotton wireworm [5] of the Southern States, and the dry-land wireworm [6] and inflated wireworm [7] of the dry-farming region of the Northwest and the wheat regions of the Northern Middle West.

[1] *Agriotes mancus* Say.
[2] *Melanotus communis* Gyll. and other species of Melanotus.
[3] *Limonius californicus* Mann.
[4] *Limonius confusus* LeC.
[5] *Horistonotus uhlerii* Horn.
[6] *Corymbites noxius* Hyslop.
[7] *Corymbites inflatus* Say.

KINDS OF WIREWORMS, AND WHERE FOUND.

Wireworms are the young or worm stage of several kinds of hard-shelled beetles popularly known as "click-beetles," "skipping jacks," "snapping beetles," etc. These names are all derived from the beetles' unique habit of snapping the forepart of the body when placed on their backs or held between the fingers. This habit is undoubtedly of use to the beetles in righting themselves when accidentally overturned and may also be a means of escape from their natural enemies. Wireworms are elongate, more or less cylindrical, and have a very highly polished skin. They measure, according to kind, from one-half inch to 3 inches in length. They have three pairs of short legs near the head end of the body. The color usually is yellow or reddish brown. The cotton and corn wireworm (fig. 4) is very different in appearance from all other wireworms.

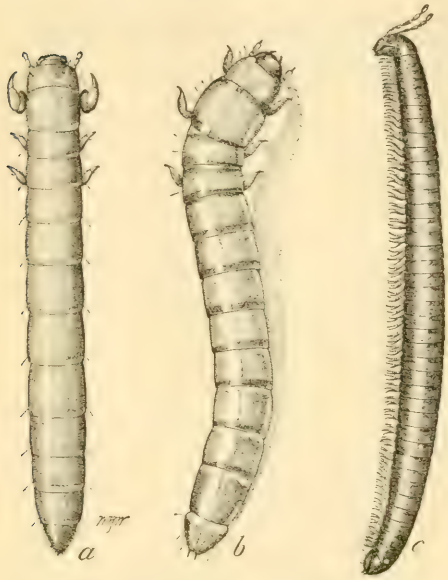

FIG. 1.—Larvæ likely to be mistaken for wireworms; *a*, False wireworm; *b*, mealworm; *c*, "thousand legger." All enlarged. (Author's illustrations.)

The name wireworm is erroneously applied to the false wireworms of the Western States (fig. 1, *a*), and the mealworms found in granaries (fig. 1, *b*). In many parts of the country root webworms also are wrongly called wireworms, and the name is incorrectly applied to several kinds of "thousand leggers" (fig. 1, *c*).

True wireworms are among the five worst pests to Indian corn and among the 12 worst pests to wheat and oats. They are also important enemies to many other crops, notably potatoes and sugar beets. They constitute a group which is probably one of the two most difficult groups of insects to control. In the last part of this bulletin the results of recent investigations as to control measures are set forth.

These insects are destructive to cereal and forage crops in the larval or worm stage only, although the beetles of some kinds do considerable damage to the blossoms of fruit trees. Wireworms attacking cereal and forage crops confine their attention to the seeds, roots, and underground stems and live almost exclusively underground. The damage is first noticed immediately after seeding, when they attack the seed, eating out the inside and leaving only the hulls.

This, of course, results in a poor stand. In such cases, by digging into the hill, the wireworms may be located. When they are very numerous they often consume an entire seeding, and, aside from the extra labor and the cost of reseeding, this delays injuriously the planting of the crop. If this be corn in the Northern States, the part of the season remaining is too short to bring it to maturity, and, except for the fodder, the crop is a failure. Where wireworms are present, even in small numbers, corn usually makes a poor stand, so that the replanting of missing hills is necessitated.

Several hundred kinds of beetles, the young of which are wireworms, occur in North America. Many of these, however, are of little immediate importance to the farmers, as they live in rotten logs, under moss, or on the roots of weeds, or prey upon other insects. The destructive wireworms are found in nearly all parts of the United States. Some of these, such as the wheat wireworm and the corn wireworm, abound in heavy moist soils rich in vegetable matter. Some, as the inflated wireworm and the dry-land wireworm, prefer well-drained soils, and still others, like the corn and cotton wireworm, are most destructive on high sandy land which is very poor in vegetable matter. As the several kinds of wireworms have such varying habits they can not all be controlled in the same way, and a variation in method is required for each of the several groups. For this reason it is quite necessary to be able to determine what kind of wireworm is doing the damage.

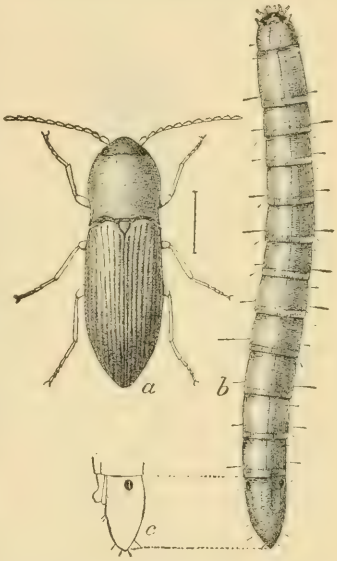

FIG. 2.—The wheat wireworm: *a*, Adult beetle; *b*, larva; *c*, side view of last segment of larva. All enlarged. (From Chittenden.)

THE WHEAT WIREWORM.

The adult, or beetle, of the wheat wireworm is brown and a little over one-fourth inch in length (fig. 2, *a*). The wireworm itself (fig. 2, *b*) is pale yellow, evenly cylindrical, and very shiny. When full grown it measures about 1 inch in length and is about as thick as the lead in a pencil. This wireworm can be easily recognized by the two dark spots near the base of the tail (fig. 2, *c*), and it is one of the commonest wireworms in the northeastern and middle-western United States. It is normally a grass feeder, living on the roots in

sod, and when its natural food supply is abundant it produces no appreciable disturbance in the meadows. When the sod land is broken, however, these wireworms gather in the drill rows or hills of corn, which is the usual crop to follow sod in the eastern United States, and often cause an absolute failure of the crop by destroying the seed and eating off the roots of such plants as may sprout. They also sometimes bore into the underground part of the stem of the plant. This wireworm is, therefore, usually more destructive on land recently broken from sod. However, in many cases the damage is more severe the second year following plowing from sod than the first. This is probably due to the fact that the wireworms feed upon the recently turned-down sod the first year, but are forced to attack the cultivated crop the second year, because by that time the sod has entirely decomposed. The wireworms spend three years in the soil before changing to beetles.

LIFE HISTORY.

The beetles come out of the ground in the early spring, during April and May. They then fly about and deposit their eggs in grasslands, the female beetles burrowing into the ground or under rubbish to deposit their eggs. The young wireworms feed during the ensuing summer and pass their first winter about half grown. The following spring they resume feeding and feed throughout the second summer, passing their second winter as full-grown wireworms. The third spring they again resume feeding, which they continue until early in July. They then leave the plants and form small earthen cells in the ground, and in these they transform to beetles. During the remainder of that summer and the third winter the beetles stay in the cells in which they transformed; then, during the fourth spring of their life they come out of the ground to lay their eggs.

CROPS ATTACKED.

The wheat wireworm feeds upon the seeds and roots of corn, potato tubers, wheat roots, carrots, turnips, and the underground stems of string beans, cucumbers, and cabbage, more or less seriously damaging or destroying the same.

REMEDIAL MEASURES.

When the land is intended for corn the following year, in order to counteract the ravages of the wheat wireworm, sod land should be plowed immediately after the first hay cutting, usually early in July. This land should be cultivated deeply throughout the remainder of the summer. Land that is in corn and badly infested should be deeply cultivated, even at the risk of slightly root-pruning the corn.

This should be continued as long as the corn can be cultivated, and as soon as the crop is removed the field should be very thoroughly tilled before sowing to wheat. In regions where wheat is seeded down for hay, any treatment of infested wheat fields is precluded. Where wheat is not followed by seeding to other crops, the field should be plowed as soon as the wheat is harvested; this kills the worms by destroying their food supply and preventing proper hibernation.

A thorough preparation of the corn land and a liberal use of barnyard manure or other fertilizer will often give a fair stand of corn in spite of the wireworms, a vigorous stand often being able to produce roots enough to withstand the depredations of several wireworms. Though not always practicable, the interposing of crops not severely attacked by wireworms, such as field peas and buckwheat, between sod and corn would materially reduce the number of wireworms in the soil at the time the crop is planted.

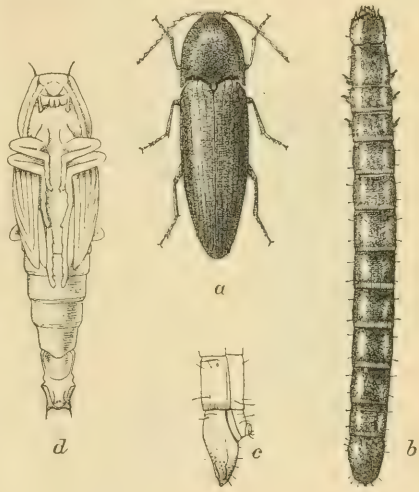

FIG. 3.—One of the corn wireworms: *a*, Adult; *b*, larva *c*, last segments of same; *d*, pupa. All enlarged. (From Chittenden.)

THE CORN WIREWORMS.

The beetles of the corn wireworms (fig. 3, *a*) measure from one-half to three-fourths inch in length, and they vary in color from light reddish brown to almost black. The wireworms (fig. 3, *b*) are reddish brown, about 1¼ inches long, cylindrical in shape, and always have three slight lobes or projections on the tail. These wireworms are pests to cereal and forage crops in the Middle Atlantic States, the New England States, and the Mississippi Valley.

LIFE HISTORY.

The beetles of these wireworms emerge in the spring and deposit their eggs in grasslands. The corn wireworms, however, spend a considerably longer time in the soil than the wheat wireworms. In some cases the corn wireworms live in the ground as long as six years. They change to beetles during August, and some beetles spend the following winter in the cell in which they transform. The beetles of some kinds of corn wireworms apparently spend the winter under the bark of decaying trees.

REMEDIAL MEASURES.

The corn wireworms are almost exclusively confined to poorly drained and heavy soils. Heavily liming and thoroughly tile-draining land infested with these wireworms would undoubtedly prove beneficial. The thorough cultivation of waste land, especially along drainage ditches and creeks, during midsummer, and the deep cultivation of crops and fallow land at the same time would destroy large numbers of them.

THE MEADOW WIREWORMS.

The meadow wireworms, including the sugar-beet wireworm and the confused wireworm, do far more damage than they are generally given credit for. In the Pacific Northwest they damage corn and potatoes and other truck crops. They have also been found doing considerable damage in the New England States and the upper Mississippi Valley. In the Northwest they seem to be much more destructive on irrigated lands than on the dry-farming lands, while in the eastern United States they seem to be confined to poorly drained areas, as are the corn wireworms. Meadow wireworms look very much like the dry-land wireworm and can be easily distinguished from the other wireworms which are important as crop pests by the forked tail. The meadow wireworms attack corn, potatoes, tomatoes, onions, cabbage, radishes, turnips, horse-radish, spinach, sugar beets, and alfalfa. They burrow into the underground parts of the plants, often killing corn, tomatoes, cabbage, or onions. They do not seem to attack beans or peas, and these crops might be of considerable value in clearing badly infested fields prior to seeding to corn. The meadow wireworms spend three years in the ground and change to beetles during July and August of their third summer.

REMEDIAL MEASURES.

Thorough tile draining of infested fields in the eastern areas and deep cultivation during July and August wherever possible will destroy large numbers of these wireworms. As most of this poorly drained land is inclined to be acid, the tilth will be greatly improved by the addition of lime at the rate of about 2 tons to the acre, using air-slaked lime. The use of lime, however, has been treated very fully in both Government and State publications, and it would be advisable for the farmer to apply to the State or Federal authorities for the rate and kind of lime to use in his particular case.

On irrigated land experiments are being made to determine remedial measures.

THE CORN AND COTTON WIREWORM.

The beetle of the corn and cotton wireworm (fig. 4, *a*) is small, cylindrical, and dusky brown, measuring a trifle over three-sixteenths inch in length. The "worm" (fig. 4, *b*) is very unlike any of the other wireworms. It is not hard and wiry, but soft and elongate. The body usually is white and apparently is composed of 26 joints.

When full grown this wireworm is about as thick as a heavy packthread. Unlike most of the eastern wireworms, which are usually most destructive on low-lying, heavy, or poorly drained lands, this wireworm seems to be far more numerous on the higher parts of the field in light sandy soils. The corn and cotton wireworm is one of the most troublesome pests of the southern United States. Bad outbreaks have occurred in the Carolinas, Missouri, Arkansas, and southern Illinois. Corn, oats, rye, cowpeas, crab grass, Johnson grass, peanuts, cotton, tobacco, sweet potatoes, and watermelons are all attacked, corn suffering the most of all. Investigations are now under way to determine efficient remedial measures for this insect.

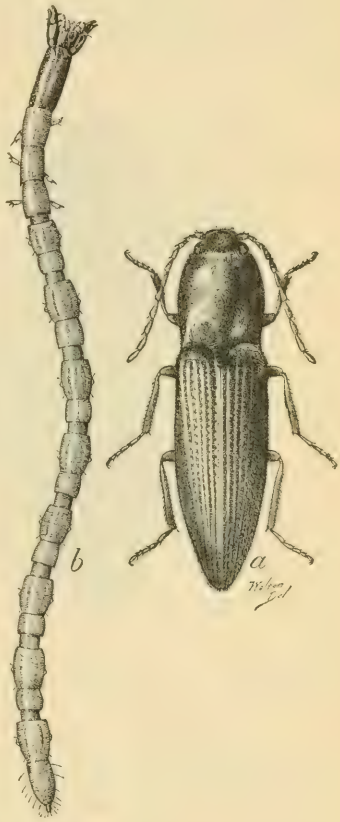

FIG. 4.—The corn and cotton wireworm: *a*, Adult beetle; *b*, larva. Enlarged. (Author's illustration.)

THE DRY-LAND WIREWORM AND THE INFLATED WIREWORM.

The dry-land wireworm (fig. 5) and the inflated wireworm, which are very similar in appearance, seem to be confined to the dry-farming regions of the Northwest and to the wheat regions of the northern Middle West. Early in May the beetles emerge from the ground. They are about in large numbers during May and in June, when the females burrow into the ground to deposit their eggs. These wireworms do not confine their egg laying to grasslands, but deposit the eggs in grain fields and weedy fallow lands. The wireworms spend two full summers and a part of a third in the ground, transforming to beetles during July and August of the third summer, the beetles not coming from the ground until the fourth spring. Thus the wireworms, as such, are in the ground during the growing season of three years. The beetles of the inflated wireworm have been observed in large numbers on the blossoms of wild rosebushes, where they were apparently eating the petals. The beetles of the dry-land wireworm are a little later in coming out of the ground, emerging in June and July. In the dry-land regions this wireworm feeds only during the spring, burrowing down from 4 to 8 inches below the surface to pass the hot, dry months.

REMEDIAL MEASURES.

As will be seen from the life history, the generations about to become adults are inactive wireworms from June to August, transforming to beetles in the early part of August. The resting and transforming wireworms usually are found at a depth of 4 to 8 inches, and any disturbance of the soil to such depth at this time will destroy them. The ground is very hot during this period of the year, and the air extremely dry, so that even the resting wireworms that are not actually crushed by the cultivation soon succumb to drying when their cells are broken open. The usual farm practice in the

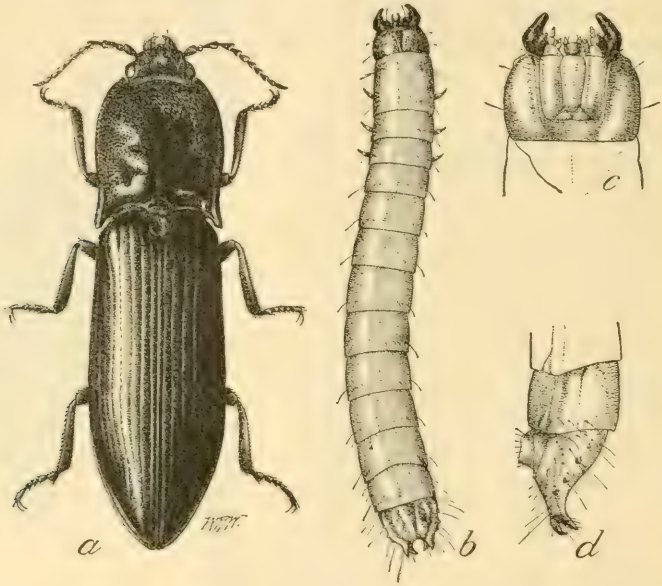

FIG. 5.—The dry-land wireworm: *a*, Adult; *b*, larva; *c*, under surface of head of larva; *d*, side of last segment of larva. *a*, *b*, Enlarged; *c*, *d*, more enlarged. (Author's illustration.)

dry-land farming region of the Northwest where these wireworms are most troublesome may be roughly outlined as follows:

Immediately after seeding the wheat in early spring the summer fallow land is plowed to a depth of from 4 to 7 inches. This usually is done in April, but if horses and help can be spared from seeding, the summer fallow is plowed as early in the spring as the land can be worked. The next operation on the fallow land is disking the land in June or early July to maintain the dust mulch and kill the weeds and volunteer wheat. Some of the more progressive farmers now practice fall plowing of the stubble and disking the fallow land only in the spring. The field is disk-harrowed early in the spring if the land has run together during the winter and is caked, otherwise the land is harrowed with a drag or spring-tooth harrow. It is then

seeded and dragged and receives no further treatment until harvest. The seeder usually is set to sow at a depth of about 3 inches, although, if the moisture content is high enough, 1 inch is considered sufficient. Wheat hay is used extensively in this country, and is cut while the wheat is in the dough stage, which usually is from July 4 to July 15. The wheat crop is harvested from August 1 to September 15. In order to destroy wireworms this practice should be altered in the following manner:

(1) Disk or drag-harrow the summer fallow as early as possible in the spring in order to produce a dust mulch and thereby conserve the accumulated winter moisture. (2) Continue the disking as often as is necessary in order to maintain the dust mulch and keep down the

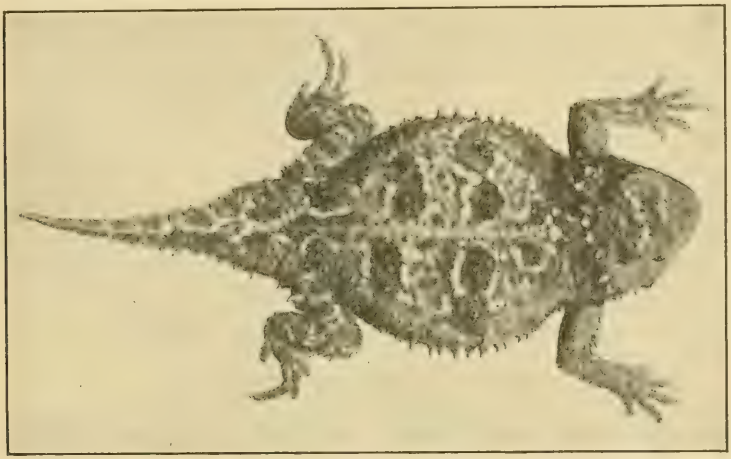

FIG. 6.—A horned toad, an enemy of the western wireworms. (Author's illustration.)

weeds. (3) Plow the summer fallow in July or early in August and immediately drag. (4) Plow the stubble as soon as the crop is removed.

As these wireworms are of three different ages in most infested fields, and as only about one-third of these are in the pupal stage, changing to beetles each year, it is evident that the first year of this practice will not show marked results. However, if the practice is continued for two years it will reduce the number of these pests very considerably. Aside from its beneficial results in killing insects, this method of handling the land will materially reduce the weeds, the early disking merely softening up the soil and allowing all the weed seeds present to sprout, the entire crop of weeds subsequently being destroyed by the summer plowing. By the present method of farming, the weed seeds are turned down to such a depth that many can not germinate; but they lie dormant, and sprout whenever they happen

to be brought to the surface by subsequent cultivation. One crop of weed seed is in this manner often a pest for several succeeding years.

NATURAL ENEMIES OF WIREWORMS.

Most of our common song birds feed rather extensively upon both the beetles and the wireworms themselves, and any regulation designed to protect these birds and encourage their increase will undoubtedly be effective in reducing the number of these pests. In the desert regions of the West the small lizards, commonly called sand toads or horned toads (fig. 6), feed very extensively upon wireworms and their beetles and should be protected by the farmers of these regions. The examination of the stomachs of a large series of field frogs collected on the shores of Lake Oneida, in upper New York, proves beyond a doubt that these frogs are of enormous value in destroying the beetles of the wheat wireworm when these beetles are laying their eggs in the grasslands. These frogs are slaughtered in enormous numbers every year for the summer hotel trade. Any regulation which would put a stop to this practice would be of great value to the agricultural interests of this and similar sections. Wireworms are not severely attacked by parasites, so far as is known. However, several parasites are being studied with the object of using them as a means of controlling wireworms. The introduction of several known fungous diseases also is being studied.

USELESS REMEDIAL MEASURES.

The use of various substances upon the seed corn and wheat has proven of little value in fighting wireworms. The application of certain commercial fertilizers recommended as insecticides is also of but little use. The application of lime is not effective as an insecticide, but is of value in rendering the soil more easily drained. Late fall plowing has probably been the most universally recommended method of combating these insects. However, at least for the kinds of wireworms on which this method has been tried, it is quite useless. Trapping the larvæ with baits of poisoned vegetables may be of some value under intensive methods of farming, but it is impracticable in the growing of field crops.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 731 MAY 23, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE TRUE ARMY WORM[1] AND ITS CONTROL.

By W. R. WALTON, *Entomological Assistant, Cereal and Forage Insect Investigations.*

INTRODUCTION.

This publication is designed to convey to the farmer, in a brief and simple manner, the natural history of the true army worm, a caterpil-

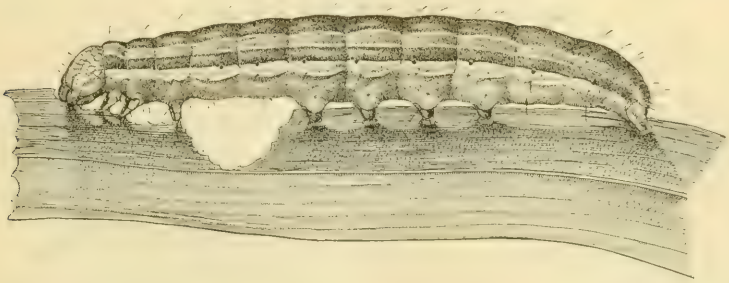

FIG. 1.—The true army worm: Full-grown larva or caterpillar. Enlarged. (Original.)

lar which from time to time becomes enormously destructive to growing cereals, and sometimes to forage crops; to give him a summary of the information necessary for its control; and especially to urge upon him the necessity for constant vigilance in the combat with this insect.

The true army worm (fig. 1) is often confused in the public mind with the fall army worm,[2] "overflow worm," or "grass worm" as

[1] (*Heliophila*) *Cirphis unipuncta* Haw.; order Lepidoptera, family Noctuidae.
[2] *Laphygma frugiperda* S. & A.

NOTE.—This bulletin is of general interest to crop growers everywhere, and especially east of the Rocky Mountains.

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it is known in some of the extreme Southern States. The latter insect always originates in the South and travels northward as the summer advances. The western army cutworm[1] also is occasionally mistaken for the true army worm, but it occurs in destructive abundance only throughout the regions west of the Mississippi River. Both of the latter insects will be treated in a separate publication.

GENERAL DESCRIPTION.

The fully developed parent of the army worm (figs. 2, *a*, and 5) is a moth or "miller" measuring about 1½ inches across the expanded wings. It is brownish-gray in color, having a single small white spot near the center of the front pair of wings, the hind wings being somewhat darker along the hind edges. Although these parents of the worm sometimes are very numerous, they fly only at night and are therefore often entirely overlooked by the farmer. The stage of the insect most familiar to him is the full-grown, striped, nearly naked caterpillar (figs. 1 and 2, *b*), usually discovered in the act of devouring his crops and in most cases after having already destroyed the greater portion of the infested crop.

WHERE THE ARMY WORM OCCURS.

The true army worm is probably a native of North America, although it is also found in South America. It occurs throughout most of the United States east of the Rocky Mountains, including the States bordering the western banks of the Mississippi and the Missouri Rivers. It also has been found in New Mexico, Arizona, and California. It is not known from the Rocky Mountain Plateau region. (See fig. 3.)

ECONOMIC IMPORTANCE AND MANNER OF INJURY.

The loss in money to the farmer by army worms in the past has been exceedingly great, and although no exact estimate is possible, it is safe to say that in the Eastern States alone many millions of dollars' worth of grain and forage crops have disappeared down their throats during the past 30 years.

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[1] (*Chorizagrotis*) *Euxoa auxiliaris* Grote.

FIG. 2.—Stages and work of the true army worm and some of its insect enemies: *a*, Parent or moth; *b*, full-grown larva; *c*, eggs; *d*, pupa in soil; *e*, parasitic fly, *Winthemia quadripustulata*, laying its eggs on an army worm; *f*, a ground beetle, *Calosoma calidum*, preying upon an army worm, and, at right, Calosoma larva emerging from burrow; *g*, a digger wasp, *Sphex* sp., carrying an army worm to its burrow; *h*, *Enicospilus purgatus*, a wasplike parasite of the army worm. All about natural size. (Original.)

The army worm injures crops in but one way, and that is by eating away all the tender portions of the leaves, the immature seed, and sprouts, and when numerous it may even devour the plants down to the very ground. The more important and by far the most conspicuous injury is always inflicted by the nearly full-grown caterpillar, whose greed and capacity for food are almost unbelievable. The pupa takes no food. The moth subsists principally upon the nectar gathered from flowers.

FOOD PLANTS.

The army worm feeds by preference upon grasses, both wild and cultivated; next, upon the grasslike grains, such as the several varie-

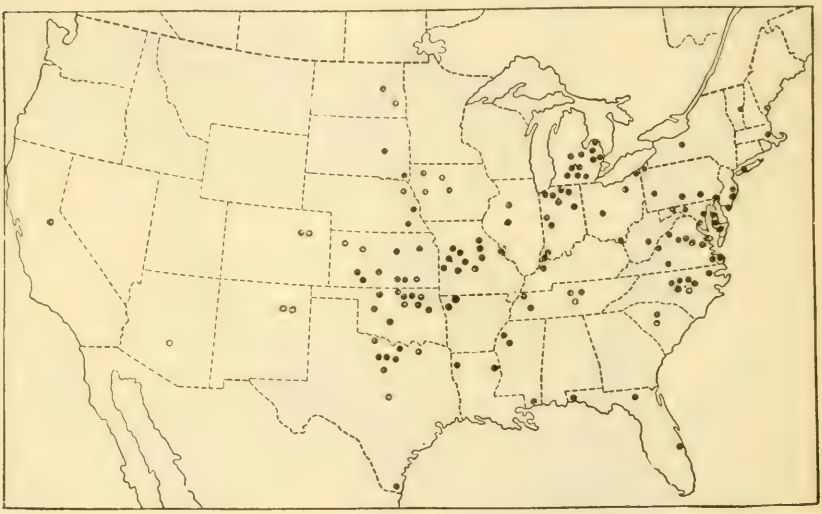

FIG. 3.—Map showing localities in the United States in which the true army worm has been destructive. (Original.)

ties of millet, which suffer severely during outbreaks of the insect. Wheat in its unripe stages, corn, oats, and rye seem to be preferred in the order named. In some portions of the country alfalfa also suffers injury; apparently damage to this crop occurs only in the Southwestern States—Texas, Oklahoma, New Mexico, and Arizona. Occasionally clover is attacked, but such occurrences are rare.

WHERE INVASIONS OF THE ARMY WORM COME FROM.

The true army worm usually appears in the fields very suddenly, and it seems quite certain that the moths at times fly in great numbers for many miles, in the direction of the prevailing winds, and alight in a body to deposit their eggs at some place favorable to the development of their offspring. This fact accounts for the sudden

appearance of the army worm in regions far removed from any known source of infestation. The moth, however, seems to be present in small numbers, over most of the area in which it occurs, during a portion of every year, but this fact does not account for the sudden great invasions which occur from time to time.

WHEN INVASIONS MAY BE EXPECTED.

Generally speaking, outbreaks of the true army worm are more common following cold, backward springs and should be looked for first in neglected portions of fields upon which rank growths of wild grasses or lodged and fallen unripe grain are to be found. These should be examined frequently and closely, especially during late April, May, June, and early July, in order to discover the small greenish caterpillars, which may be found in great numbers feeding near the surface of the ground under the sheltering, overhanging leaf blades.

LIFE HISTORY.

The army worm, like many other common insect pests, has four forms or stages, as follows: First, the parent moths or millers, which seek out rankly growing grass or grasslike grains, such as millet, upon which they lay their eggs (fig. 2, *c*). From these eggs hatch the little caterpillars or "worms," which feed and grow rapidly. When full grown they shed their skins and change to the brown pupa or resting stage, usually beneath the surface of the soil. From these pupæ come the parent moths, which in turn mate and lay their eggs, thus providing for another brood of caterpillars. There are usually three generations of caterpillars in any one year, but seldom or never two successive outbreaks in any given locality.

THE EGG STAGE.

The eggs are laid by the parent moths at night, usually in the folded blades or under the leaf sheaths of grains and grasses (fig. 2, *c*). These resemble small white beads, each considerably smaller than the head of a common pin, and are deposited in masses or rows on the plants selected. Moist or shaded spots usually are chosen for this purpose by the moths, many of which seem to congregate and lay their eggs in the same locality. These eggs hatch in from 8 to 10 days and from them come the very small greenish caterpillars or "worms."

THE CATERPILLAR OR LARVAL STAGE.

When the caterpillars are first hatched they are very tiny and, although countless thousands of them may be present, they consume,

at this time, comparatively little food. Feeding near the ground, sheltered from view by the overhanging grain or grasses, they almost invariably escape the notice of the farmer. If the colony of worms can be discovered at this stage of their growth the infestation usually can be stamped out completely by prompt and vigorous measures, such as spraying with arsenicals or covering with straw and burning over the infested spot.

As the young worms grow and feed, their skins become too small for them, so presently they split and are shed, and the caterpillars begin feeding more greedily than ever. This occurs several times during the life of the caterpillar, until the worm becomes full grown. The time required for full growth is from 3 to 4 weeks. The full-grown army worm (figs. 1 and 2, *b*) is a nearly naked, smooth, striped caterpillar, about 1½ inches long. Its general color is usually greenish, and the stripes, one along each side and a broad one down the center of the back, are dark and often nearly black. The stripe along the back usually has a fine, light-colored, broken stripe running down its center. The color of the body between the dark stripes varies from greenish to reddish brown. The head is greenish brown speckled with black.

When an army of these worms is at work in a field the champing of their jaws is plainly to be heard, as they greedily devour every blade in sight. In this stage the army worm frequently consumes all of the food supply near the place where it has developed from the egg. When such is the case the caterpillars mass together and crawl away in a body in search of other food. It is this habit which has gained for the insect the popular name of "army worm." The massing together of the worms affords the farmer an opportunity of destroying them in great quantities by mechanical methods described on a following page of this publication. When the full-grown caterpillars cease feeding they usually burrow into the soil to the depth of a few inches and by dint of twisting and turning form a cavity or cell therein. The worm then begins to shrink and shorten, after which the skin splits and is shed and the pupa appears beneath it. When the worms are very numerous many of them pupate on the surface of the ground, hidden under clods, boards, or bunches of dried grass and fallen grain.

THE PUPA OR RESTING STAGE.

The pupa (figs. 2, *d*, and 4) or resting stage of the true army worm resembles a date seed in size and shape, but is more pointed at one end. In color it is at first a reddish or chestnut brown, becoming almost black as the time for emergence of the moth approaches. Its

skin or covering is smooth and tough, and the pupa is unable to move any portion of its body excepting its tail, which it wriggles vigorously upon being disturbed. If the soil in which the pupæ are resting be lightly cultivated during this time and the pupæ thrown to the surface, most of them will be killed by exposure to the weather, crushed by the cultivating implements, or eaten during the day by birds or at night by skunks which roam the fields and consume great quantities of such food.

FIG. 4.—The true army worm: Pupa. Enlarged. (Original.)

THE PARENT OR MOTH STAGE.

When the moth (figs. 2, *a* and 5) crawls forth from the pupal case it has not yet developed its wings, which are crumpled and folded in pad-like masses on each side of its back. It usually crawls up the stem of some plant and begins to expand its wings, waving them back and forth slowly for about an hour, by which time they are completely developed and the insect is capable of flying. However, if undisturbed, the moths will usually remain at rest for several hours before flying away to mate and lay their eggs. It takes from 7 to 8 weeks for the insect to develop from the egg to the adult or moth.

After the moths have expanded their wings they do not grow any larger; the small moths are not the young of larger moths, but the

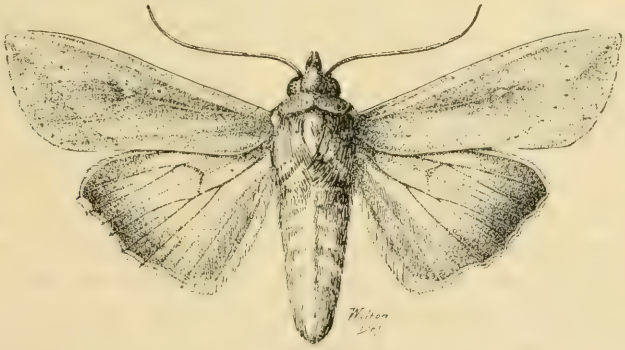

FIG. 5.—The true army worm: Parent or moth. Enlarged. (Original.)

male moth or parent of the army worm is usually considerably smaller than the female.

The army worm moth is strongly attracted to lights at night and frequently swarms of these moths are seen about lights out of doors shortly before an outbreak of the army worm. Farmers would

therefore do well to learn to recognize the moth at sight, as in this way they could be warned of the probable subsequent injurious abundance of the caterpillar. The moths may readily be known by their plain brownish-gray appearance and the presence of a single very small, almost pure white speck or spot near the center of each of the front wings (see figs. 2, *a* and 5). The moths seldom or never lay their eggs near the spot where they have developed and frequently fly for many miles before doing so. Thus there are seldom two successive outbreaks during the year in any given locality. It is not yet definitely known where or how the army worm lives over the winter, but the indications are that it does so in the partially grown caterpillar stage.

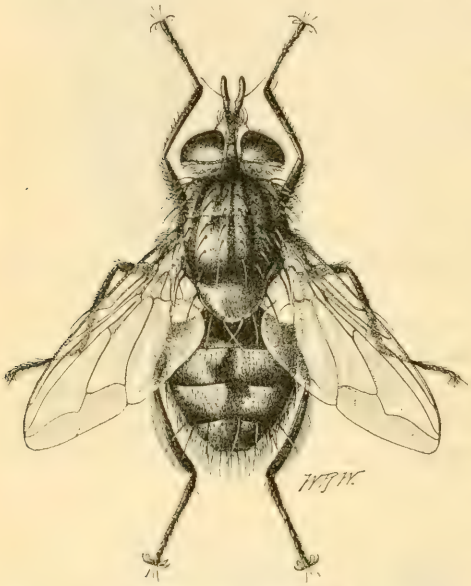

FIG. 6.—*Winthemia quadripustulata*, a fly parasitic on the true army worm: Adult. Much enlarged. (Original.)

HISTORY OF THE ARMY WORM IN THE UNITED STATES.

The army worm has been known as a serious pest on cereal and forage crops in the United States since early colonial times. As early as the year 1632 it is recorded as injuring corn in New England by Peter Kalm, a Swedish naturalist who traveled in this country. In the year 1743 a great outbreak of the army worm is recorded as having occurred throughout that portion of the country now known as the North Atlantic States. From then down to the present time the insect has hampered agriculture and robbed the farmer mercilessly at comparatively short but irregular intervals of time. The most recent serious invasion occurred during the summer of 1914, at which time the entire agricultural region east of the Rocky Mountains and north of the Gulf States suffered to a greater or less degree. From the past history of the insect the farmer may confidently expect to be compelled to cope with it from time to time, and he should ever be on the alert during the spring and early summer months in order to discover the pest before it has made serious inroads upon his crops.

NATURAL ENEMIES.

Most fortunately for the farmer, the army worm has many natural enemies among the native insects, reptiles, birds, and mammals.

INSECT ENEMIES.

One of the commonest and most effective of its insect foes is a medium-sized gray fly[1] (fig. 6), closely resembling, and slightly larger than, the house fly. This parasite sticks its eggs fast to the skin of the caterpillar (fig. 2, *b* and *e*) and the quickly hatching maggots bore through the skin into the flesh, where they soon devour the entire inside portions of the army worm's body. These flies multiply rapidly and often become so numerous as to control the army worm completely in a given locality.

FIG. 7.—Larva of the army worm surrounded by silken cocoons of the wasplike parasite *Apanteles militaris*. About natural size. (Original.)

Another common insect foe is a very small wasplike creature (fig. 7),[2] which pierces the caterpillar with its sting or ovipositor, laying its eggs inside the army worm's body, where they quickly hatch and, the maggots having eaten their fill, bore their way outward and spin little silken cocoons in a mass together, somewhat resembling grains of rice entangled in a mass of cotton. This parasite is also sometimes numerous enough to be of great service in controlling the pest.

Several other insect enemies serve more or less efficiently in combating the army worm. Some of these are shown in figure 2, *f*, *g*, *h*.[3]

WILD BIRDS AND OTHER ENEMIES.

According to the records of the United States Biological Survey, more than 40 species of native wild birds are known to eat the army worm in its various stages. Among the most important of these are the following: Crow blackbird or grackle, yellow-headed blackbird, chipping sparrow, bluebird, prairie hen, and European starling. Domestic fowls of all kinds will greedily devour the caterpillars and pupæ if allowed to roam over infested fields. Skunks and toads also undoubtedly eat thousands of the army worms, both caterpillars and

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[1] *Winthemia quadripustulata* Fab.
[2] *Apanteles militaris* Say.
[3] *Calosoma Calidum* Fab., (*Ammophila*) *Sphex* sp., and *Enicospilus purgatus* Say.

pupæ. These birds and other animals should therefore be encouraged and protected by the farmer by all possible means.

CONTROL MEASURES.

WATCHFULNESS AS A FACTOR.

The importance of watchfulness, on the part of the farmer, as a factor in combating the army worm can not be too greatly emphasized. Upon the discovery of the pest in its younger stages depends very largely the possibility of stamping out an infestation before serious injury to crops has occurred. The farmer should examine his meadows frequently during the spring and early summer months, particularly those planted to timothy, bluegrass, and especially millet. He should not be satisfied with looking merely at the surface of the stand; the thicker and longer the growth, the greater the danger from the army worm. The grass or grain should be parted with the hands in various parts of the field and the lower portions of the growth closely examined, in order to discover the presence of the small, greenish caterpillars, and if such be found in any number the area covered by the infestation should be determined and vigorous action taken at once to destroy the worms before they become large enough to begin their journey to other portions of the farm. If the infested spot be small, the grass or grain can be mowed off and straw scattered over the spot and burned, thus destroying the worms. If the caterpillars have become distributed over a considerable area, this can be marked off by stakes and the crop sprayed heavily with a mixture of Paris green at the rate of 1 pound to 50 gallons of water. In case this poison is used, care should be exercised in preventing stock from gaining access to the poisoned grass or grain and being injured or killed by eating it. It is far better to sacrifice a portion of the crop, if the destruction of the pest can be accomplished thereby, because if the army worms are not destroyed they will take the crop anyway and probably devastate other portions of the farm.

POISONED BAITS.

Poisoned baits of varying composition have long been used as a means of destroying the many different species of cutworms and also the army worm. An efficient bait of this kind may be prepared and used as follows: To 50 pounds of wheat bran and 1 pound of Paris green or 2 pounds of arsenate of lead add the juice of one-half dozen oranges or lemons. Then bring the mass to a stiff dough by adding low-grade molasses or sirup, preferably the former, and scatter the mixture broadcast in small pieces throughout the infested field. This poisoned bait may be safely used in alfalfa

and cornfields where it is desired, if possible, to save the crop for forage purposes.

MECHANICAL MEASURES.

In case the worms are not discovered until they have begun to travel in a mass, they can usually be destroyed by furrowing or ditching (fig. 8) completely around the infested area. In attempting to cross such ditches the worms will fall into them and can easily be destroyed by crushing them with a log dragged back and forth through the ditch or furrow. If shallow post holes are sunk in the bottom of the ditch at intervals of about 20 feet, the worms will crawl along the ditch bottoms and fall into the holes, where

FIG. 8.—Ditch prepared to entrap marching army worms. A log, dragged back and forth through the ditch, crushes the worms which have fallen into it. (Original.)

they may be destroyed by crushing or other means. If the subsoil be of such a nature that water penetrates it but slowly, the post holes may be partially filled with water, on the top of which a layer of coal oil or petroleum may be poured. Upon falling into such holes, the worms are almost immediately destroyed without further action on the part of the farmer.

SUMMARY OF CONTROL MEASURES.

(1) Watch fields of growing grass and grain carefully, especially the meadows, during the spring and early summer months, in order

to discover the army worms before they have a chance to become full grown and spread over the entire farm. When the worms are discovered at work do not lose a minute, but attack them vigorously by means of the measures outlined in the foregoing pages.

(2) In case the worms are crawling in a body, surround them with a furrow or ditch and crush them with a log drag as they fall into it.

(3) Poison them by spraying crops not intended for forage purposes with 1 pound of Paris green to 50 gallons of water, or with 2 pounds of arsenate of lead to 50 gallons of water. In case the Paris green is used on tender plants, like corn, 2 pounds of freshly slaked lime should be added to 50 gallons of the mixture. This is to prevent burning the tender plants. Where spraying is not practicable, the use of the poisoned bran bait, mentioned on page 10 of this publication, is strongly recommended.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 733 JUNE 9, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE CORN AND COTTON WIREWORM[1] IN ITS RELATION TO CEREAL AND FORAGE CROPS, WITH CONTROL MEASURES.

By EDMUND H. GIBSON,
Scientific Assistant, Cereal and Forage Insect Investigations.

INTRODUCTION.

During the three years which have elapsed since the investigation of the corn and cotton wireworm (fig. 1, *b*) was begun there have been constant requests by farmers and others for remedial measures, and it is in answer to these requests that the present paper has been prepared. The injury, as in the case with other wireworms, is caused by the feeding of the worm-like young or larvæ of slender beetles, known as "click beetles" or "snapping beetles," upon the roots, sprouts, and underground stems of plants which are thereby weakened and stunted or killed.

FIG. 1.—The corn and cotton wireworm: *a*, Adult, or beetle; *b*, larva, or wireworm. Much enlarged. (Hyslop.)

EXTENT OF DAMAGE BY THE CORN AND COTTON WIREWORM.

These wireworms have been known totally to destroy corn throughout fields of large acreage. However, this is not usually the case and the attack is most frequently concentrated in "spots" scattered throughout the field, the plants in these spots being wholly destroyed. In other parts of the field there may be slight injury as shown by the dwarfed ap-

[1] *Horistonotus uhleri* Horn; order Coleoptera, family Elateridae.

NOTE.—The object of this bulletin is to set forth in a popular form what is known of the habits of the destructive corn and cotton wireworm, in order that farmers and planters may more effectively carry out control measures and be able better to handle infested areas, that the injury may be reduced to a minimum.

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pearance of the plants, which may later produce 50 per cent or more of a normal yield.

The wireworms are ravenous feeders, often cutting off all the roots of a plant. They are especially destructive during the two months before they transform to adults. A single half-grown wireworm is capable of killing a young corn sprout and severely injuring a plant from 6 to 8 inches in height. Therefore it can be seen that when there is a concentrated attack by many wireworms in one hill the plants have but small chance of surviving.

DESCRIPTION OF THE INSECT IN ITS DIFFERENT STAGES.

The parent of the corn and cotton wireworm (fig. 1, *a*) is a small dark brown click-beetle, or "snapping beetle," measuring about one-fourth of an inch in length. The eggs (fig. 2) laid by this beetle are white and nearly round; when first deposited they are translucent, but in a day or two become opaque. The young wireworms, or larvæ, after hatching from the eggs are minute, measuring from an eighth to three-sixteenths of an inch in length. When from half to full grown (fig. 1, *b*) they may be described as "soft, membranous, and elongate." The body, which is usually white, is apparently composed of 26 segments, or joints, every third segment being swollen. The last segment is simply pointed. The head, which is yellow, is long and slender, and has a pair of prominent, dark brown jaws. When full grown these larvæ measure about an inch in length and are but slightly thicker than pack thread. The pupæ (fig. 3), to which the larvæ change before becoming adult beetles, have the same general color as the larvæ and are about five-sixteenths of an inch long and nearly an eighth of an inch thick. Each pupa occurs in a small earthen chamber constructed by the larva.

FIG. 2.—Egg of the corn and cotton wireworm. Much enlarged. (Original.)

All stages of the insect are spent in the ground except the adult or beetle, which only enters it at the time of egg deposition.

FIG. 3.—Pupa, or resting stage, of the corn and cotton wireworm. Much enlarged. (Original.)

There are a number of other species of wireworms which are often found associated with this wireworm about the roots of corn and others of its food plants. The corn and cotton wireworm can be easily distinguished from these, however, by its light creamy color and threadlike form, as most other wireworms are stouter and usually either reddish or brownish.

WHERE THE INSECT OCCURS.

Reports show that the corn and cotton wireworm has been destructive in the Carolinas, Illinois, Missouri, Arkansas, and Missis-

sippi. This would indicate a wide distribution, probably a wider one than the mere records reveal, and it is possible that the species may occur throughout the entire eastern half of the United States. Its occurrence is closely related to the distribution of soils of light sandy type, as it is known that the immature stages exist only in such soils. Occasionally an adult has been collected several miles from sandy locations, but its presence there was more than likely due to its own flight from the field of its origin. In some localities this species is referred to as the "sandy-spot wireworm."

PLANTS ATTACKED.

Cotton and corn constitute the principal food plants of this wireworm, and of the cereal and forage crops in the South the greatest damage is done each year to corn. The wireworms, besides feeding upon the roots of corn and cotton, are known to attack oats, rye, cowpeas, crab grass, and Johnson grass. Sweet potatoes, peanuts, tobacco, watermelons, and the roots of a wild bamboo are also among the food plants of this wireworm. The adults have been observed feeding on stems of cowpeas and on young, tender leaves of corn and crab grass.

CHARACTER OF THE INJURY.

Corn plants infested by this wireworm become wilted and stunted, with leaves of a bluish shade, brown at the tips, which stand out from the stalks stiffly instead of bending over gracefully as in a healthy plant. Deprived of most of the roots through the work of the larvæ of this wireworm, the plant can be pulled up with little effort. Weak plants soon succumb, leaving gaps in the rows, but the more vigorous plants put forth new roots in abnormal numbers. These are matted together and distorted, and although the plants survive, only "nubbins" are produced. The infestation is not confined to the impoverished areas, for there may be larvæ among the roots of tall and apparently healthy plants. Rolling land infested by this insect presents a patchy appearance, the sandy knolls standing out distinct and bare, although overgrown later with weeds, particularly crab grass, briers, and morning-glories. For a long time there was a theory among farmers that lightning caused the injury to corn which is now rightly attributed to this wireworm.

In the case of cowpeas, the fibrous roots suffer most, the thicker roots being perforated, so that the plants become yellow and dwarfed, and fail to vine.

Cotton is injured in the early stages by larvæ boring into the seed and injuring the very young plants, checking the growth so much that the plant dies or struggles along only to produce little or no cotton.

LIFE HISTORY OF THE SPECIES.

Beetles of the corn and cotton wireworm (fig. 1, *a*) are abroad in the fields from early June until the last of August. The eggs (fig. 2), which are laid in groups of from 3 to 20 in the soil about the roots of corn, cowpeas, and other food plants, are deposited, for the most part, during late June and July. These hatch in from 8 to 11 days into the young wireworms or larvæ (fig. 1, *b*) which immediately commence feeding upon the roots. The exact duration of the period of development in the soil has not yet been determined, but the information now at hand indicates that the species lives in the larval stage for two years and possibly three. It is true that adults are to be found each year, but this is probably due to overlapping broods. During May or June each full-grown larva constructs a small earthen cell in the soil and in this it changes to a pupa (fig. 3). The pupal stage averages 12 days in length and during this time the pupa is almost motionless and takes no food. After this it transforms to the adult or beetle. As is usually the case, the duration of the egg and pupal stages varies with temperature and moisture conditions.

HABITS OF THE LARVÆ, OR WIREWORMS.

The larvæ, or wireworms, feed upon the roots of their food plants throughout the summer months and up to about the first of October, and during this time are found within 18 inches of the surface of the ground, the depth depending upon the moisture content of the top soil. During a hot, dry spell the wireworms remain from 12 to 18 inches below the surface, but after a rain they can be found within 2 inches of the surface.

With the approach of cold weather they begin a general downward movement, which accounts for the farmer's inability to locate them during the late fall and winter months. At Charleston, Mo., December 1, 1914, they were found in the sand at the remarkable depth of 5 feet. This appeared to be the average depth at which they remained during the winter in this locality, observations showing the depth to vary from 4 to 6 feet. From these facts it will be seen that fall or winter plowing would be useless as a control or remedial measure.

By the last of February in some localities, or as soon as winter breaks up, the larvæ gradually make their way to within 2 to 3 feet of the surface. By the middle of April they are numerous within 6 inches of the surface of the ground. From the time the larvæ travel downward in the fall until they return to the top soil they eat practically nothing. In laboratory experiments, larvæ remained alive and healthy in cages of moist pure sand, without organic food, for six months.

The larvæ are quick of movement and wriggle vigorously when disturbed. In indoor rearing cages they are found to be keenly susceptible to an overabundance of moisture, and, too, will die if the cage soil is allowed to get excessively dry.

Cannibalism is common among them, especially under artificial rearing conditions, but the fact that as many as 106 larvæ have been found in one hill of corn is evidence that this habit does not exist to any great extent in the field when there is plenty of plant food at hand.

HABITS OF THE ADULTS, OR BEETLES.

The adults, or beetles, are also very quick of movement. Immediately upon being disturbed they "snap" themselves and fall to the ground from the leaf or stem upon which they are resting. On the ground they feign death for a few moments, then quickly scamper off to a hiding place. The adults feed very little, hence any injury which they might cause would be hardly perceptible.

They evidently fly well, as they have been collected in quantities around lights at night. This would probably explain the fact that adults have been collected several miles from the nearest sandy spot or field. The author, however, has never seen them fly in the daytime.

The female beetles will not deposit eggs in soil which is crusted over or baked, but leave such a field and search for one which is covered by a dust mulch, or which has recently been plowed. This fact is important and should be taken into account when control measures are being considered, since cultivation at the time the beetles are most numerous means that excellent conditions are given the females for depositing their eggs.

NATURAL ENEMIES.

Comparatively few natural enemies of this wireworm have been noted. No internal parasites have been reared from any stage of the species. Birds feed upon all kinds of wireworms including those of the genus Horistonotus.

INEFFECTUAL REMEDIAL MEASURES.

PLOWING.

Late fall and winter plowing as a method of reducing the numbers of the pest by turning up and exposing the larvæ to the elements is of no value, as the wireworms are at this time at such depths in the soil that they would not be disturbed by the plowing. Plowing or cultivating for this purpose at other times of the year is of little avail as the wireworms are so quick of movement that almost as soon

as exposed they are again hidden in the loosened soil. Even chickens or turkeys are not sufficiently alert to catch many.

TRAPPING ADULT BEETLES.

Trapping the beetles at night by means of strong lights above open vessels containing water or kerosene would in no way prove practical, especially on a large scale.

POISONING.

Killing the wireworms by placing poisoned baits in the soil around the hills of corn is not practical, nor will the treating of seeds with poisons or repellents assist in protecting the plants from wireworm attacks. Turning under wood ashes, as a remedy against wireworms, has proved to be of no avail.

EFFECTIVE CONTROL AND REMEDIAL MEASURES.

The following control measures are formulated from the study of the habits of the insect, and are based on results of such measures carried on over a period of two years. It must be remembered that as this species has been under investigation for only three years, the following remedial measures are subject to more or less modification.

HASTENING EARLY PLANT GROWTH.

The most important factor in reducing injury by this wireworm is the employment of methods which hasten early plant growth in the spring, the object of stimulating growth being to enable the plants the better to withstand the attacks of the wireworms. In the case of corn this consists of early planting—at least by April 20 for southeastern Missouri and northeastern Arkansas—followed by frequent cultivation until the middle of June.

CROP ROTATION.

Any system of crop rotation after harvesting the corn may be carried out, and a winter cover crop such as wheat or rye is advised. Pasturing this during winter months and turning it under in the spring is very beneficial, since humus is thus added and the sandy soil is thereby stiffened. An infested field should not be planted to corn two years in succession.

If a catch crop of red clover can be obtained it is an excellent one to come in the rotation for two or three years. Such combinations as wheat and clover are to be recommended for southeastern Missouri, as they not only afford two crops a year from the

same field, but also permit the soil to remain undisturbed during the period when the female beetles are laying their eggs. As stated elsewhere in this bulletin, the females prefer loose soil for egg deposition, especially soil which has been recently cultivated or plowed.

A system of handling the ground and crops so that the soil will not be disturbed from the middle of June until the middle of August is one of great importance, and it may prove to be the most beneficial step in eradicating the wireworms from an infested area. This may be brought about by omitting from the rotation such crops as would normally require summer cultivation.

The supposition that an infestation of the corn and cotton wireworm is worse following cowpeas seems to be unfounded.

MANURING.

The manuring of infested areas has long been recommended as the best control measure. The theory was advanced, especially by some farmers, that the manure turned under is actually distasteful to the larvæ and kills them outright. Although this is not the case, nevertheless the turning under of manure and cover crops has the effect of adding humus to the top soil; and, as it is known that the larvæ can not long survive except in sandy soils, it is well to spread as much manure as possible on infested areas and to turn it under.

LAND RESTING.

If it were practicable to allow the infested fields to lie idle, or "lay out," as it is termed, for a period of three years, this would no doubt prove the most effective means of getting rid of the pest, since by leaving the ground undisturbed a crust would be formed on the surface through which the majority of adult wireworms could not emerge. It would also serve to prevent the few emerging adults, as well as those flying in from other fields, from entering the soil for egg deposition. However, this practice naturally will not often appeal to the farmer.

SUMMARY OF CONTROL MEASURES.

(1) Plant infested fields to such crops as do not require summer cultivation, such as clover, cowpeas, soy beans, or grasses.

(2) Add humus to the light sandy spots by turning under manure and cover crops.

(3) If grain crops be planted, allow stubble to remain until the middle of August.

(4) If corn must be grown, plant early and do everything possible to hasten rapid growth. Do not plant corn two years in succession.

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE RELATING TO INSECTS INJURIOUS TO CEREAL AND FORAGE CROPS.

AVAILABLE FOR FREE DISTRIBUTION.

Cotton Bollworm. (Farmers' Bulletin 290.)
Common White Grubs. (Farmers' Bulletin 543.)
The Chalcis-fly in Alfalfa Seed. (Farmers' Bulletin 636.)
The Grasshopper Problem and Alfalfa Culture. (Farmers' Bulletin 637.)
The Hessian Fly. (Farmers' Bulletin 640.)
Alfalfa Attacked by the Clover-root Curculio. (Farmers' Bulletin 649.)
The Chinch Bug. (Farmers' Bulletin 657.)
Wireworms Destructive to Cereal and Forage Crops. (Farmers' Bulletin 725.)
The True Army Worm and its Control. (Farmers' Bulletin 731.)
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Southern Corn Rootworm, or Budworm. (Department Bulletin 5.)
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The Oat Aphis. (Department Bulletin 112.)
The Alfalfa Caterpillar. (Department Bulletin 124.)
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Leafhoppers Affecting Cereals, Grasses, and Forage Crops. (Entomology Bulletin 108.) Price, 20 cents.
Spring Grain-aphis or Green Bug. (Entomology Bulletin 110.) Price, 25 cents.
Preliminary Report on Alfalfa Weevil. (Entomology Bulletin 112.) Price, 15 cents.

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FARMERS' BULLETIN

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

CONTENTS.

FLYTRAPS AND THEIR OPERATION.

By F. C. BISHOPP, *Entomological Assistant.*

INTRODUCTION.

Flytraps have a distinct place in the control of the house fly and other noxious fly species. There is a general tendency, however, for those engaged in combating flies to put too much dependence on the flytrap as a method of abating the nuisance. It should be borne in mind that flytrapping is only supplementary to other methods of control, most notable of which is the prevention of breeding either by completely disposing of breeding places or by treating the breeding material with chemicals.[1]

It may be said that there are two main ways in which flytraps are valuable: (1) Catching flies which come to clean premises from other places which are insanitary and (2) capturing those flies which invariably escape in greater or less numbers the other means of destruction which may be practiced. Furthermore, the number of flies caught in traps serves as an index of the effectiveness of campaigns against breeding places.

[1] Results obtained in experiments with the use of chemicals against fly larvæ in manure are presented in Bulletins Nos. 118 and 245 of the Department of Agriculture. The biology of the house fly and the various methods of control are discussed in Farmers' Bulletin 679.

NOTE.—This bulletin is intended to give directions for the use of a supplementary means of controlling flies; it is adapted to all parts of the United States.

Fly trapping should begin early in spring if it is to be of greatest value. Although comparatively few flies are caught in the early spring, their destruction means *the prevention of the development of myriads of flies by midsummer.*

KINDS OF FLIES CAUGHT.

The various species of flies which are commonly annoying about habitations or where foodstuffs are being prepared may be divided roughly into two classes: (1) Those which breed in animal matter, consisting mainly of the so-called "blowflies"; and (2) those which breed in vegetable as well as in animal matter. In the latter group the house fly is by far the most important. The stable fly is strictly a vegetable breeder, as are also certain other species which occasionally come into houses and may in rare cases contaminate foodstuffs. The stable fly, which breeds in manure or decaying vegetable matter, and the horn fly, which breeds in cow manure, are blood-sucking species, and can be caught in ordinary flytraps in comparatively small numbers only. The kind of flies caught depends to a considerable extent on the material used for bait. In general the house fly and other species which breed in vegetable matter are attracted to vegetable substances, while the blowflies will come most readily to animal matter. This rule, of course, is not absolute, as flies are less restricted in feeding than in breeding habits, and, as is well known, the house fly is attracted to a greater or less extent to any moist material, especially if it has an odor.

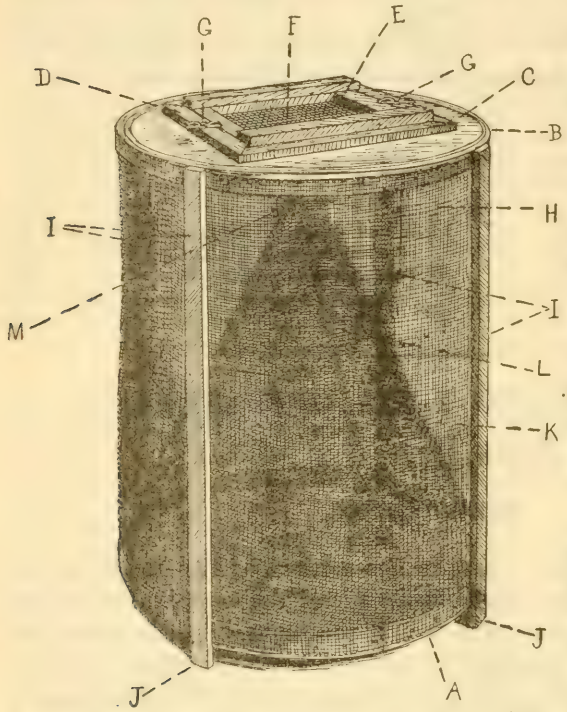

FIG. 1.—Conical hoop flytrap; side view. *A*, Hoops forming frame at bottom. *B*, Hoops forming frame at top. *C*, Top of trap made of barrel head. *D*, Strips around door. *E*, Door frame. *F*, Screen on door. *G*, Buttons holding door. *H*, Screen on outside of trap. *I*, Strips on side of trap between hoops. *J*, Tips of these strips projecting to form legs. *K*, Cone. *L*, United edges of screen forming cone. *M*, Aperture at apex of cone. (Author's illustration.)

TYPES OF TRAPS.

The same general principle is involved in nearly all flytraps in use, though superficially they may appear quite different. The flies are attracted into a cage, as it were, by going through a passage the entrance of which is large and the exit small, so there is little chance of the flies, once in, finding their way out again. This principle is modified to fit different conditions. For instance, the window trap, devised by Prof. C. F. Hodge, catches the flies as they endeavor to enter or leave a building; the garbage-can trap, for which Prof. Hodge is also to be credited, catches the flies that have entered garbage cans; and the manure-box trap retains the flies bred from infested manure put into the box.

The attractant used to induce flies to enter traps may consist of (1) food, as in baited traps; (2) odors, as in window traps placed in windows from which odors are emitted; and (3) light, as in traps on manure boxes. Of course light is an important factor in the success of all traps, for, as is well known, flies have a marked tendency to go toward the light, and they usually enter the trap by flying toward the light after having been attracted beneath it by bait or after entering a room in search of food.

CONICAL TRAPS.

A number of traps of this general type are on the market, but most of these are of small size. Nearly all are constructed with a dome instead of a cone, and on this account the catching power is reduced about one-third. Moreover, the farmer, dairyman, or anyone with a few tools can construct traps at a small fraction of the sale price of ready-made ones.

THE CONICAL HOOP TRAP.

A trap which appears from extensive tests made by Mr. E. W. Laake and the author to be best for effective trapping, durability, ease of construction and repair, and cheapness may be made as follows:

The trap consists essentially of a screen cylinder with a frame made of barrel hoops, in the bottom of which is inserted a screen cone. The height of the cylinder is 24 inches, the diameter 18 inches, and the cone is 22 inches high, and 18 inches in diameter at the base. Material necessary for this trap consists of four new or secondhand wooden barrel hoops, one barrel head, four laths, 10 feet of strips 1 to 1½ inches wide by one-half inch thick (portions of old boxes will suffice), 61 linear inches of 12 or 14 mesh galvanized screening 24 inches wide for the sides of the trap and 41 inches of screening 26 inches wide for the cone and door, an ounce of carpet tacks, and two turn-buttons, which may be made of wood. The total cost of the material for this trap, if all is bought new at retail prices, is about 65 cents. In practically all cases, however, the barrel hoops, barrel head, lath, and strips can be obtained without expense. This

would reduce the cost to that of the wire and tacks, which would be 45 cents. If a larger number of traps are constructed at one time the cost is considerably reduced.

One of these traps is illustrated in figures 1 and 2. In constructing the trap two of the hoops are bent in a circle (18 inches in diameter on the inside), and nailed together, the ends being trimmed to give a close fit. These form the bottom of the frame (*A*), and the other two, prepared in a similar way, the top (*B*). The top (*C*) of the trap is made of an ordinary barrel head with the bevel edge sawed off sufficiently to cause the head to fit closely in the hoops and allow

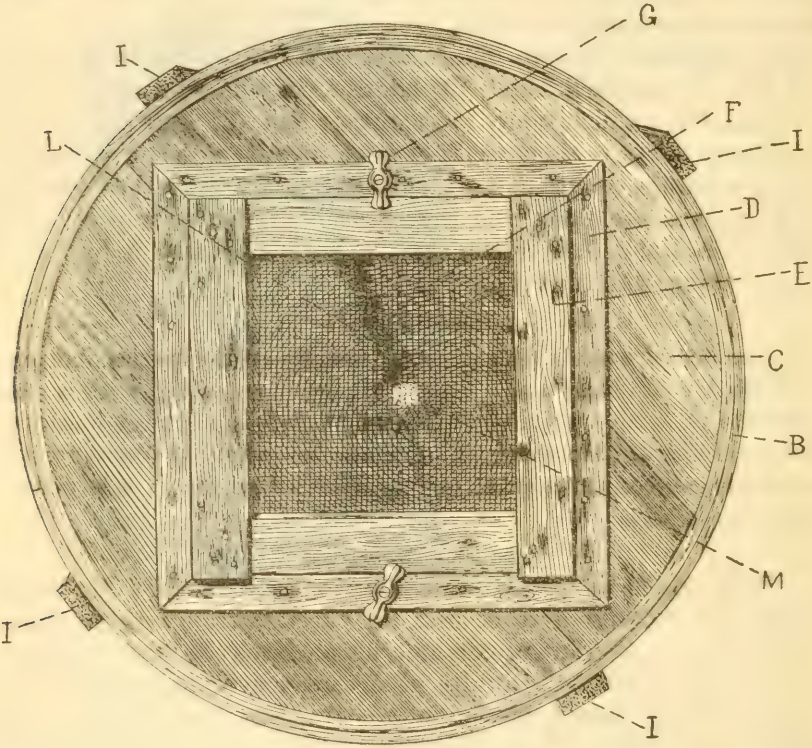

FIG. 2.—Conical hoop flytrap; top view. Letters designate parts as in figure 1. (Author's illustration.)

secure nailing. A square, 10 inches on the side, is cut out of the center of the top to form a door. The portions of the top (barrel head) are held together by inch strips (*D*) placed around the opening one-half inch from the edge to form a jamb for the door. The door consists of a narrow frame (*E*) covered with screen (*F*) well fitted to the trap and held in place (not hinged) by buttons (*G*). The top is then nailed in the upper hoops and the sides (*H*) formed by closely tacking screen wire on the outside of the hoops. Four laths (*I*) (or light strips) are nailed to the hoops on the outside of the trap to act as supports between the hoops, and the ends are allowed to pro-

ject 1 inch at the bottom to form legs (J). The cone (K) is cut from the screen and either sewed with fine wire or soldered where the edges meet at (L). The apex of the cone is then cut off to give an aperture (M) 1 inch in diameter. It is then inserted in the trap and closely tacked to the hoop around the base.

The construction of a cone of any given height or diameter is quite simple if the following method be observed. It is best to cut a pattern from a large piece of heavy paper, cardboard, or tin. Figure 3 illustrates the method of laying out a cone of the proper dimensions for the above trap. An ordinary square is placed on the material from which the pattern is to be cut; a distance (22 inches) equal to the height of the cone is laid off on one leg of the square at A, and a distance (9 inches) equal to one-half of the diameter of the base of the cone is laid off on the other leg at B.

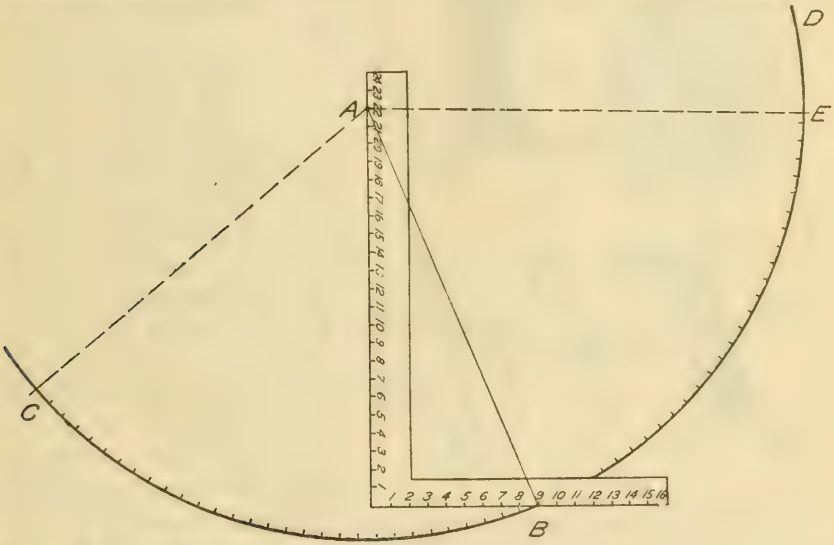

FIG. 3.—Method of laying out a pattern for the construction of a cone. Cut out on curved line C to E and on dotted lines from A to C and A to E. (Author's illustration.)

and a line is drawn between the points A and B. With the distance between these points as a radius and with the point A as a center, the portion of a circle $C\ D$, is drawn. With a pair of dividers, the legs of which are set 1 inch apart, or with the square, lay off as many inches on the arc $C\ D$, starting at C, as there are inches around the base of the cone, which in this case is about 56½ inches, reaching nearly to the point E. Then add one-half inch for the lapping of the edges of the cone, and one-half inch which is taken up when the cone is tacked in, thus making a total distance from C to E of 57½ inches. Draw a line from A to C and another from A to E, and cut out the pattern on these lines and on the arc from C to E, as shown in figure 3. The edges AC and AE are then brought together, lapped one-half inch and sewed with wire or soldered. After the aperture

of the cone is formed by cutting off the apex, as previously described, it is ready for insertion in the trap.

In order to figure the distance around the base of a cone of any given diameter, multiply the diameter by 3.1416 or $3\frac{1}{7}$.

The height of the legs of the trap, the height of the cone, and the size of the aperture in the top of the cone, each are of importance in securing the greatest efficiency.

OTHER FORMS OF CONICAL TRAPS.

Conical traps with steel frames are satisfactory, but they are less easily rescreened and it is more difficult to keep the lids closely fitted. These, of course, can be constructed only by shops with considerable equipment. Traps constructed with a wooden disk about the base of the cone, and a similar disk around the top to serve as a frame, or those with a square wooden frame at the bottom and top with strips up the corners are fairly satisfactory. It should be borne in mind that the factor which determines the number of flies caught is the diameter of the base of the cone, if other things are equal. Therefore the space taken up by the wooden framework is largely wasted, and if it is too wide it will have a deterrent effect on the flies which come toward the bait. For this reason it is advisable that the wood around the base of the cone should be as narrow as consistent with strength—usually about 3 inches.

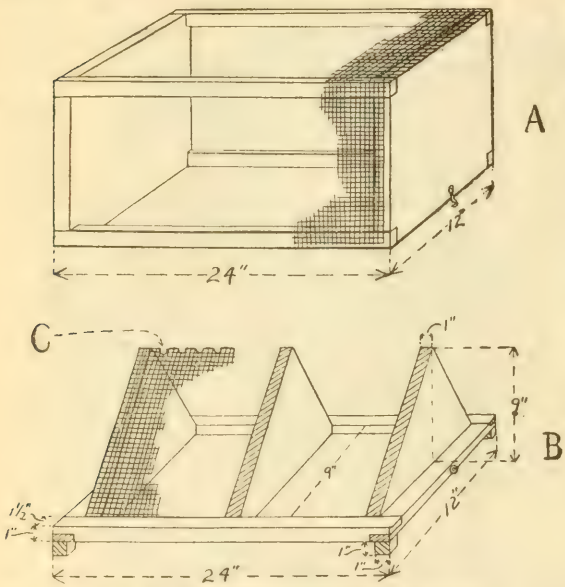

FIG. 4.—Tent flytrap. When the trap is set up the screen box, *A*, fits on the base, *B*, and two pans of bait are placed beneath the tent. *C*, Hole in screen at apex of tent. (Original.)

Under no condition should the sides or top of the trap be of solid material, as the elimination of light from the top or sides has been found to decrease the catch from 50 to 75 per cent.

TENT TRAPS.

The tent form of trap has been widely advocated in this country, but recent experiments indicate that it is much less efficient than the

cone trap, and usually as difficult to construct and almost as expensive. The size of these traps may vary considerably, but one constructed according to the dimensions given in figure 4 will be found most convenient. The height of the tent should be about equal to the width of the base, and the holes (*C*) along the apex of the tent should be one-half to three-fourths of an inch in diameter and 1 inch apart. The box (*A*) should be provided with hooks to pass through eyes on the base (*B*). Small blocks 1 inch thick are nailed beneath the corners of the tent frame to serve as legs.

GARBAGE-CAN TRAPS.

As previously mentioned, Prof. Hodge has adapted the cone trap to use on the lids of garbage cans. It is not advisable to use this trap except where garbage cans are sufficiently open to admit flies. In such cases a hole may be cut in the lid of the can and one of the small balloon traps which are obtainable on the market attached over the hole. To make the trap effective the edges of this lid should extend well down over the top of the can. The lid should be held up slightly so as to allow the flies to pass under, but not high enough to admit direct light. Practically speaking, the garbage forms the bait for this trap, and when inside the can the flies are attracted to the light admitted through the trap. It is really advisable to have the garbage cans fly proof, so as to prevent danger of fly breeding within them rather than to depend on traps on the lids, which necessarily allow odors to escape. A garbage can with a trap attached is illustrated in figure 5.

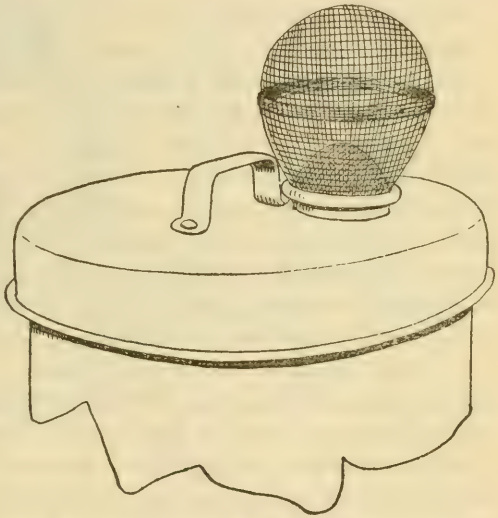

FIG. 5. Top of garbage can with small balloon flytrap attached. (Original.)

MANURE-BOX TRAPS.

Manure pits or boxes are desirable for the temporary storage of manure, especially in towns and cities. These have been widely advocated, but the difficulty has been that manure often becomes infested before it is put into them, and flies frequently breed out before the boxes are emptied and often escape through the cracks. To obviate these difficulties a manure box or pit, with a modified

tent trap or cone trap attached, is desirable. Mr. Arthur Swaim, of Florida, has devised a form of manure trap consisting of a series of screen tents with exit holes along the ridges of these, over which is a screen box. The latter retains the flies as they pass through the holes in the tents. The entire trap is removable.

In order to retain the fertilizing value of manure to the greatest extent it is advisable to exclude the air from it as much as possible and to protect it from the leaching action of rains. This being the case, there is really no necessity for covering a large portion of the top of the box with a trap, but merely to have holes large enough to attract flies to the light, and cover these holes with ordinary conical traps, with the legs cut off, so the bottom of the trap will fit closely to the box. The same arrangement can be made where manure is kept in a pit. In large bins two or more holes covered with traps should be provided for the escape of the flies.

Manure boxes should be used by all stock owners in towns and cities, and they are also adaptable to farms. The size of the manure bin should be governed by the individual needs, but for use on the farm it is desirable to make it large enough to hold all of the manure produced during the busiest season of the year. A box 14 feet long, 10 feet wide, and 4 feet deep will hold the manure produced by two horses during about five months. About 2 cubic feet of box space should be allowed for each horse per day. The bin should be made of concrete or heavy plank. When the latter is used the cracks should be battened to prevent the escape of flies. The bin may have a floor or it may be set in the ground several inches and the dirt closely banked around the outside. For the admission of the manure a good-sized door should be provided in either end of a large bin. A portion of the top should be made easily removable for convenience in emptying the box, or one entire end of the box may be hinged. On account of the danger of the door being left open through carelessness, it is advisable to arrange a lift door which can be opened by placing the foot on a treadle as the manure is shoveled in. The door should be heavy enough to close automatically when the treadle is released. A manure bin with flytrap attached is shown in figure 6.

Attention is directed to a maggot trap devised by Mr. R. H. Hutchison, as described in Bulletin No. 200 of the Department of Agriculture. Where large quantities of manure are produced on a farm this method of storing the manure on a platform and trapping the maggots which breed out may be more convenient than the manure bin.

WINDOW TRAPS.

Prof. C. F. Hodge has designed a trap which is really a modified tent trap adapted to use in a window. This trap is constructed so

as to catch the flies as they enter or leave through the window. It is adaptable to barns which are fairly free from cracks or other places where flies may enter. It may also be used on windows of buildings where foodstuffs are prepared and where flies endeavor to enter through the windows or escape after having gained entrance through other passageways. All openings not provided with traps should be closely screened, and on large buildings traps may be installed in every third window.

This trap is essentially a screen box closely fitted to the frame of

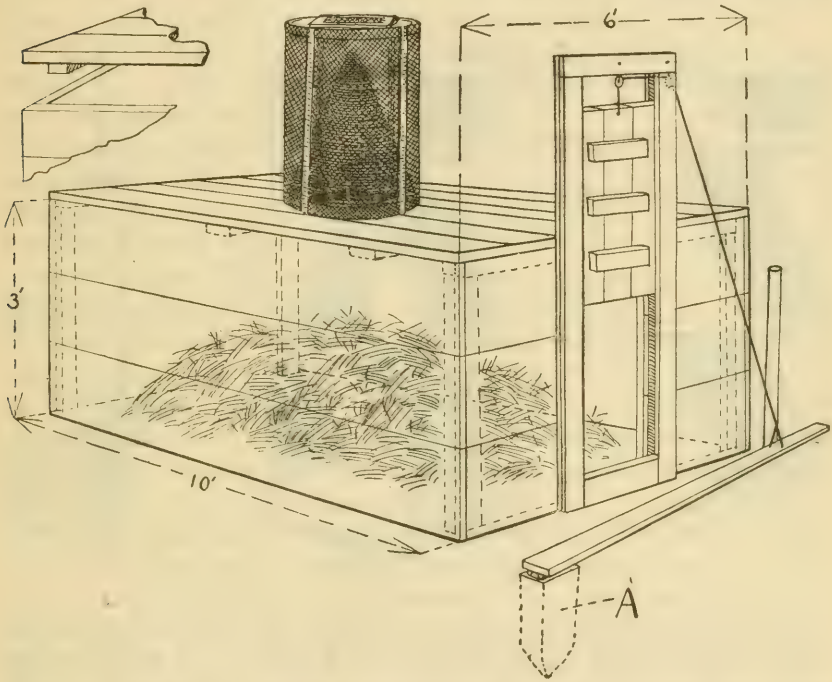

FIG. 6.—Use of flytrap in connection with manure bin. *A*, Block of wood set in ground to which lever raising door is hinged. (Original.)

a window (see fig. 7). The thickness of the box at *A* should be about 12 inches. Instead of the screen running straight down over the box on either side it is folded inward nearly to the center of the frame in V-shaped folds running longitudinally across the window. One, two, or even more folds may be made in the screen on either side. The upper side of the fold *B* should extend toward the center almost at right angles with the side of the trap, that is, parallel with the top and bottom; and the lower side *C* should slant downward as shown in the drawing. The sides of the frame may be cut out at the proper angle and the pieces *D* returned after the screen has been tacked along the edges. Along the apex (inner edge) of each fold is

punched a series of holes *E* about one-half inch in diameter and 1 inch apart. The apices of the folds on either side of the window should not be directly opposite. A narrow door *F* opening downward on hinges should be made on one side of the trap at the bottom for removal of the dead flies. The entire trap is fastened to the window by hooks so that it may be readily taken off. An additional trapping feature may be added by providing a tent trap fitted in the bottom of the box. A narrow slit is left along the base to allow the flies to enter beneath the tent. Bait may be placed under the tent to attract the flies.

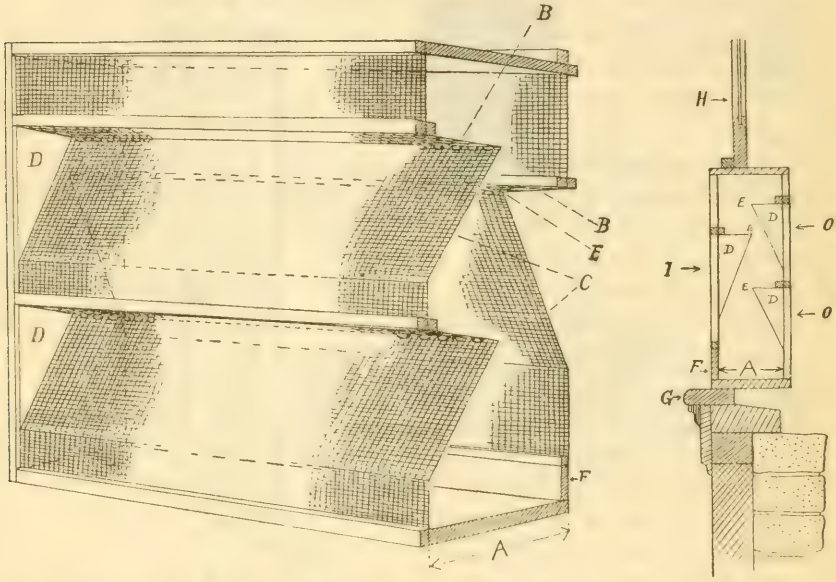

FIG. 7.—Hodge type window trap. At left, trap with end removed to show construction; at right, cross section of trap placed in a window. *A*, End of trap. *B*, Upper side of folds in screen. *C*, Lower side of folds in screen. *D*, Portion of end of trap sawed out and returned after attaching screen. *E*, Holes along apex of folds. *F*, Door for removing dead flies. *G*, Window sill. *H*, Upper window sash. *I*, Inside entrance for flies. *O*, Outside entrances. (Author's illustration.)

It has been found that the use of these window traps will aid in protecting animals in barns from stable flies and mosquitoes, and in some cases horseflies and other noxious species are caught.

BAITS FOR TRAPS.

The question of selecting the best bait for flies is an important one. As has been indicated, the kind of bait used should be governed by the species of flies which it is desired to destroy. For the most part it is the house fly which it is desired to catch, and for this insect waste beer is preeminently the best bait. In some cases

it can be procured without charge and in others it is sold at from 5 to 10 cents per gallon. On dairy farms, probably milk is the next best bait, considering its convenience. The tests indicate that milk is not more than one-third as effective as beer and rather less so than a mixture of cheap molasses and water. This mixture is prepared by adding 3 parts of water to 1 part of "black-strap" molasses and allowing it to ferment for a day or two. All baits, milk, beer, etc., are much more attractive during active fermentation. Sirup made by dissolving 1 part of ordinary brown sugar in 4 parts of water and allowing the mixture to stand a day or two to induce fermentation is almost equal to the molasses and water as a fly bait. If it is desirable to use the sirup immediately after making it, a small amount of vinegar should be added. Honey bees are sometimes caught in large numbers at this bait. When this happens some of the other baits recommended should be used. In the experiments it was found possible to secure catches equal to those obtained by using stale beer through the employment of homemade malt extract; this is slightly troublesome to make and therefore does not recommend itself for general use except in towns and cities where flytraps are being operated by individuals who give much time to this work. This extract is prepared by using 1 gallon of water to 2 pounds of ground malt. The latter may be purchased at about $1 per bushel and ground in a coffee mill. The water is heated to 135° F., the malt added, and then during a period of 45 minutes the temperature is gradually raised to 160° F. The extract is then strained off the grain, cooled, and is ready for use.

With the baits before mentioned comparatively few blowflies will be caught. For use about slaughterhouses, butcher shops, and other places where blowflies are troublesome, it has been determined that the mucous membrane from the lining of the intestines of hogs is without equal as a bait. This material, which is commonly spoken of as "gut slime," can be obtained from packing houses where sausage casings are prepared. The offensive odor of this bait renders its use undesirable near materials intended for human consumption. Another packing-house product known as blood tankage is a good fly bait when used with beer. This combination results in the capture of a large percentage of house flies. Still better results are obtainable by using "gut slime" in combination with beer. Where these materials are not obtainable fairly good catches will result from the use of fish scraps or meat scraps. With any of these baits the catches will be found not to be entirely meat-infesting flies, as actual counts have shown that the precentage of house flies in traps over such baits ranges from 45 to 75.

Overripe or fermenting fruit, such as bananas, crushed and placed in the bait pans sometimes gives satisfactory results. A combina-

tion of overripe bananas with milk is much more attractive than either one used separately. A considerable number of blow-flies as well as house flies are attracted to such baits.

BAIT CONTAINERS.

The size of the bait container in relation to the size of the trap is a very important consideration. It has been found that a small pan or deep pan of bait set in the center under a trap will catch only a small fraction of the number of flies secured by using larger, shallow containers. The best and most convenient pan for baits is a shallow circular tin, such as the cover of a lard bucket. Its diameter should be about 4 inches less than that of the base of the trap, thus bringing the edge within 2 inches of the outside edge of the trap. The catch can be increased slightly by placing a piece of sponge or a few chips in the center of the bait pan to provide additional surface upon which the flies may alight. The same kind of pans for bait may be used under tent traps. Two or more pans should be used, according to the length of the trap.

CARE AND LOCATION OF TRAPS.

In many cases fly trapping has been rendered ineffectual by the fact that the traps were not properly cared for. In setting traps a location should be chosen where flies naturally congregate. This is usually on the sunny side of a building out of the wind. It is exceedingly important that the bait containers be kept well filled. This usually requires attention every other day. The bait pans should be washed out at rather frequent intervals. This gives a larger catch and avoids the danger of flies breeding in the material used for bait. Further, it should be borne in mind that traps can not be operated successfully throughout the season without emptying them. Where flies are abundant and the bait pans are properly attended to the traps should be emptied at weekly intervals. Where flies become piled high against the side of the cone the catching power of the trap is considerably reduced. The destruction of the flies is best accomplished by immersing the trap in hot water, or still better, where a tight barrel is at hand place a few live coals in a pan on the ground, scatter two tablespoonfuls of sulphur over them, place the trap over the coals, and turn the barrel over the trap. All of the flies will be rendered motionless in about five minutes. They may then be killed by using hot water, throwing them into a fire, or burying them.

STICKY FLY PAPERS.

Sticky fly papers are of some value in destroying flies which have gained access to houses, but they have marked limitations and numerous objectionable features. For use out of doors, traps are much more effective and economical.

Dr. Crumbine, of the Kansas State Board of Health, gives the following method for preparing fly paper:

"Take 2 pounds of rosin and 1 pint of castor oil, heat together until it looks like molasses. Take an ordinary paint brush and smear while hot on any kind of paper—an old newspaper is good—and place several about the room. A dozen of these may be made at a cost of 1 cent."

POISONED BAITS.

The question of destruction of flies with poisons is somewhat out of place here, but the close relationship of poisoned baits to trapping warrants a brief statement.

Probably the best poisoned bait for house flies is formaldehyde in milk used at the rate of about two tablespoonfuls of formaldehyde to a pint of a mixture of equal parts of milk and water. This is placed in flat dishes in places frequented by flies. A piece of bread or a sponge in the dish adds to the effectiveness. Stale beer or molasses and water with 8 per cent formaldehyde added will probably also give satisfactory results. As far as possible other liquids should be removed when poisoned baits are exposed.

CAUTION.

It should be borne in mind that formaldehyde, 40 per cent, is poison about in the same proportion as wood alcohol, if taken internally. It should not be inhaled, nor should the eyes be unduly exposed to it. Special pains should be taken to prevent children from drinking poisoned baits and to prevent the poisoned flies from dropping into foods or drinks.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 735 JUNE 12, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE RED SPIDER[1] ON COTTON AND HOW TO CONTROL IT.

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Entomological Assistant, Southern Field Crop Insect Investigations.

INTRODUCTION.

By the adoption of the preventive measures described in this bulletin it is possible to avoid the losses caused by the so-called red spider (fig. 1), a minute creature which seriously injured 20,000 acres of cotton in South Carolina in 1912, and is similarly destructive in other Southern States. Injury by the red spider in cotton fields may occur from the middle of June until the middle of September. It consists in a rusting and dropping of the leaves and sometimes in the death of the affected plants over considerable portions of the fields. For many years this trouble has been called "rust" by cotton planters, who concluded from the reddening of the leaves that it was a disease. The injury, however, is caused by the presence on the cotton leaves of multitudes of small mites called "red spiders."

GENERAL APPEARANCE AND NATURE OF DAMAGE.

The presence of the pest is first revealed by the appearance on the upper surface of the leaf of a blood-red spot. As leaves become more infested they redden or turn rusty yellow over the entire surface, become folded, then turn brown and dry, and finally drop. The lower leaves usually are first attacked, but infestation spreads upward until often only the bare stalk and one or two terminal leaves remain. (See figs. 2, 3, and 4.) Such plants almost always die.

[1] *Tetranychus telarius* L., generally known as *T. bimaculatus* Harvey, and in some publications as *T. gloveri* Bks.; order Acarina, family Tetranychidae.

In severe cases the dropping of the leaves is sufficient to prevent the development of lint. The loss of foliage, however, is always accompanied by the shedding of bolls, which may amount to the total loss of fruit or merely of the younger bolls. On the plants other than cotton, which the red spider often attacks, the appearance of the injury is similar to that on cotton, although it is unusual for most plants to show the red blotching. The feeding is done by means of sharp, slender, lance-like mouth parts which are thrust well into the leaf, usually on the under surface.

Injury results from the extraction by the red spiders of the juices of the plant leaves. It is plain, therefore, that the mites can not be killed by poisons sprayed onto the leaves, which may be devoured in feeding, but must be attacked by sprays which kill by contact.

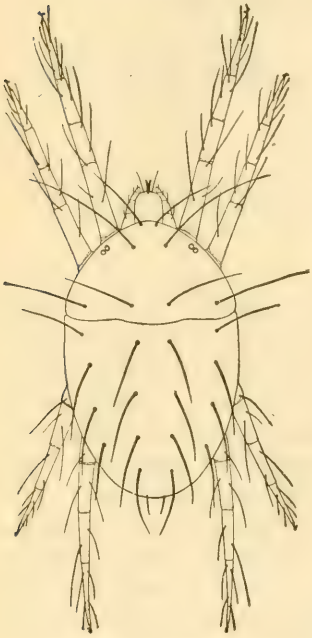

FIG. 1.—The red spider, *Tetranychus telarius:* Adult female. Greatly enlarged. (From Banks.)

EXTENT OF INJURY.

Unlike many pests the red spider does not occur continuously over large areas. Certain fields are infested while many others are free. Large fields are probably never damaged throughout, but smaller fields frequently become wholly affected. A thorough examination of all fields within 1 mile of the center of Leesville, S. C., was made during the height of the season with a view to determining the exact state of red-spider infestation in one locality. In all, 99 fields were examined as carefully as possible and about three-fourths of them were found to be infested. This occurrence was one of the severest and most general that has at any time come to the writer's attention. The worst infestation in the above-mentioned locality was one which spread from its point of origin until it extended in one direction 600 feet from the original source. (See fig. 5.) The area finally affected, semicircular in shape, comprised 13 acres, and within its boundaries the occurrence was general. While such a case as this is unusual, 4-acre or 5-acre spots with 25 to 100 per cent damage are frequently seen.

During 1912 about 20,000 acres of cotton in South Carolina were seriously infested by the red spider. Since the yield thus lost is about two-fifths of a normal crop on this area, or 2,716,000 pounds, it will be seen that at 12 cents per pound this lost lint represented a

tax of $325,920. The cotton seed lost, at ordinary prices amounting to $67,900, brought the total levy on the South Carolina planters to about $393,820. In view of the fact that North Carolina, Georgia, Alabama, and Mississippi suffer similarly and are each considerably larger than South Carolina, it is estimated that during a severe red-spider year the southeast may suffer a loss of $2,000,000 from the ravages of this pest.

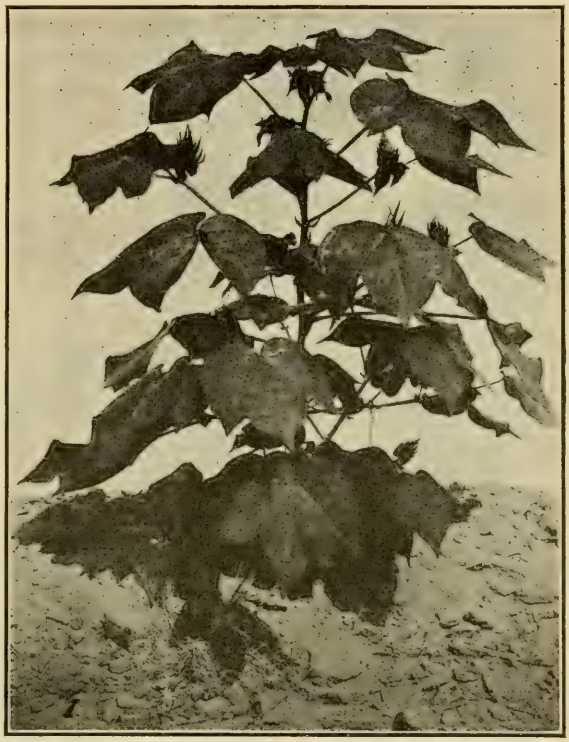

FIG. 2.—An uninfested cotton plant, growing in same field shown in figure 5, but just beyond the boundary of infestation by the red spider. (Author's illustration.)

DESCRIPTION OF THE RED SPIDER.

Both male and female red spiders are present on the plants. The color of the females is subject to considerable variation. At times it is rusty green, sometimes greenish amber, occasionally yellowish, at times almost black, but most often brick red, and a large spot of much darker color is usually seen along the back half of each side of the body. The males are considerably smaller than the females, more pointed behind, of a rusty salmon color, and the spots at the sides are not conspicuous. The red spider is in reality not a spider but a mite, and is more nearly related to the ticks than to the true spiders. As is usual with mites, both the male and the female have eight legs, but no wings. The females are less than one-fiftieth of an inch in length.

LIFE HISTORY AND HABITS.

The red spiders which pass through the winter are chiefly the mature females. Males, however, may also be seen at times during this season, and, indeed, during periods of mild weather eggs are laid and considerable development may take place. Upon several

occasions at Batesburg, S. C., all stages of the red spider have been seen in winter on plants in outdoor locations. Feeding continues more or less, depending on the temperature, on several species of plants which bear leaves throughout the winter.

FIG. 3.—Cotton plant in an early stage of infestation by the red spider. Many leaves are discolored and some of the lower ones have dropped. (Author's illustration.)

The great mass of red spiders pass the winter on wild plants, and since these support the mite during the time of year when it is most difficult for the pest to survive it is clear that the wild plants are of great importance. Among the more common of these winter plants are hedge nettle, evening primrose, Jerusalem oak, wild blackberry, sow thistle, wild geranium, and wild vetch.

With the recurrence of warm spring days, the red spiders multiply much faster until their winter food plants become too crowded to support them properly. New feeding grounds then become necessary, and migrations take place which carry them to numerous species of spring plants and weeds.

FIG. 4.—Cotton plant in well advanced stage of infestation by the red spider. Nearly all leaves, squares, and bolls have been shed. (Author's illustration.)

The first spring generation of females usually develops about March 31. From this date until about May 31, when cotton becomes attractive to the pest, the red spider advances from the winter plants in several successive migrations. During this interval five broods of red spiders usually develop, so that each wintering female by the first of June has produced, theoretically, over 300,000,000 offsprings. In the meantime most weeds and garden plants that stand in the path of the red spider's advance become infested.

During the spring and summer months the red spider, in the latitude of South Carolina, requires on an average a little less than

11 days for the completion of a generation. In an average season at Batesburg, S. C., there are 17 generations of red spiders.

In developing from the egg to the adult stage the red spider follows one or the other of two distinct courses, depending on the sex. With the female, the egg hatches in about four days to a tiny, colorless, 6-legged form known as a larva, which feeds eagerly, and in about two days in summer time sheds its skin and becomes an 8-legged form called the primary nymph. The latter feeds in a manner very similar to that of the larva, and becomes greenish or yellowish in color with conspicuous blotches at the sides. At Batesburg this stage requires a trifle over two days for completion, when the skin is again shed and the secondary nymph appears. The

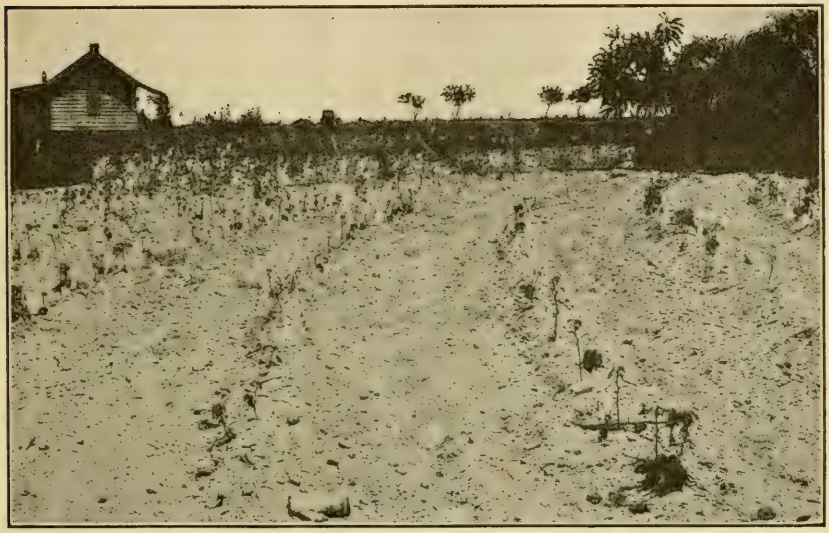

FIG. 5.—A severe example of red-spider work in a cotton field. Nearly all plants in the foreground are in the condition shown in figure 4. The source in this case was certain pokeweed stalks growing in the weed border seen in the upper right-hand corner of the figure. (Author's illustration.)

latter lives about as the preceding stages do and becomes more nearly the size and color of the adult. After about one and nine-tenths days another molt or skin shedding occurs which gives origin to the adult female. Thus, for the most favorable season, the females require about nine days to mature.

The development of the male is very similar to that of the female with the difference that the second nymphal stage is lacking. The other stages, however, are slightly lengthened, so that the male red spiders usually complete their development only one day sooner than do the females.

In establishing herself upon cotton the female selects a concave area between the under veins of the leaf and, after a brief feeding

period of about 18 hours, begins to deposit her eggs. They are usually clustered rather closely, rarely occupying an area greater in size than that of a dime.

For about 8 to 10 days the female lays usually about six eggs per day, thus making a total of about 50 to 60 eggs. Feeding continues from time to time throughout the egg-laying period. The average duration of adult life in summer, in South Carolina, is about 12 days. This period increases as the weather becomes cooler, and in winter the adults often live for 150 days.

RELATION OF WEATHER TO BREEDING.

Climatic conditions influence the development of the red spider to a marked extent. The influence may be either harmful or beneficial. In the course of the year the occurrence of the pest undergoes many changes. During December, January, and February the red spider merely maintains itself, but during March conditions usually become a little more favorable. Through April and May development progresses most rapidly, and infestation reaches its height on miscellaneous plants by June 1. Beginning about the end of September, a reduction begins in the numbers of the red spider, and this reduction continues as the weather becomes colder, until, by the end of November, the low point is again reached. Hot, dry conditions, such as occur during times of drought, hasten development, while cool, wet weather retards it. A female laying normally about six eggs per day will, upon the occurrence of a hot day, suddenly increase the number, often to 15 or 20 eggs per day, or upon a chilly day the number deposited may drop as suddenly to one egg or none.

DISPERSION.

When cotton and other annual plants die in the late fall the red spiders are forced to seek green food. Many of them manage to locate upon the several kinds of weeds (mentioned on page 4) which remain green throughout the winter. Since these wild plants occur abundantly in the borders of fields and on terraces and roadsides, the pest frequently is found on cotton the following spring, in the portions of fields where planters fail to clear these borders of weeds.

The cultivated violet occurs frequently throughout the South, and remains green through the winter. Infested violet beds have been found from Virginia to Texas, and in many cases they are the sources of infestation to near-by cotton fields. The infestation to cotton may arise directly from violets, if the beds are within a few hundred feet of cotton (fig. 6), or from a series of migrations covering considerable distances.

A peculiar sort of red-spider infestation arises from pokeweed, which occurs commonly on terraces and along field borders. Owing to its long growing period it rarely becomes heavily infested until

midsummer, so that infestation from this weed to cotton is usually noticed later than from violets or spring weeds.

It has been found that adult females are able to travel over smooth surfaces at the rate of about 5 inches per minute, or 600 feet in 24 hours. When forced to migrate through the scarcity of proper food, they commonly take to the ground and travel to other plants. During heavy rains many red spiders are dashed to the ground and carried considerable distances in the surface water, whereupon those not killed establish themselves on the plants that are near by. Heavy winds also at times blow them from place to place. When the injury becomes severe in a portion of a field it is common for the red spider to spread directly from plant to plant by means of the interweaving branches.

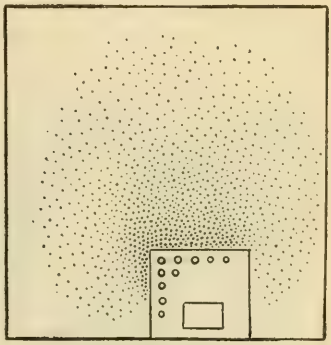

FIG. 6.—Diagram showing how violets growing in dooryard give rise to red-spider infestation in adjoining cotton field. The infestation is most severe near the yard. This diagram is typical of many cases found during 1911. (Author's illustration.)

PLANTS ATTACKED.

The red spider has been found breeding on nearly 200 species of plants, including weeds, ornamental plants, and garden and field crops. The following list of food plants, arranged in the order of their susceptibility to red-spider attack in the cotton belt, includes those most commonly infested: Cotton, cultivated violet, sow thistle, hollyhock, dahlia, garden beans, corn, tomato, onion, carnation, sweet pea, hedge nettle, nasturtium, morning-glory, clover, wild vetch, ironweed, Jerusalem oak, wild geranium, evening primrose, pokeweed, and strawberry.

NATURAL ENEMIES.

The red spider on cotton is attacked by over 30 predaceous enemies, which render valuable assistance in its control. Of these, 5 are mites, 3 are thrips, 4 are bugs, 4 are lacewing flies, 2 are midges, 4 are syrphid flies, 8 are lady beetles, and 1 is a caterpillar

REMEDIES FOR THE RED SPIDER.

PREVENTIVE MEASURES.

The solution of the red-spider problem must be accomplished through preventive efforts rather than curative, if it is to be done with economy. The location of the mites through the winter and spring, their rapid development on a few wild and cultivated plants,

and the manner of dispersion of the pest lead to the following cultural recommendations.

WEED DESTRUCTION.

Many weeds and plants serve as sources of dispersion. By destroying, during the winter and early spring, pokeweed, Jerusalem oak, jimson weed, wild blackberry, wild geranium, and other weeds in and around cotton fields, the greatest step toward red-spider control will have been taken. This plan has been tested in several instances and has given complete immunity the following season.

CONTROL ON DOORYARD PLANTS.

A few kinds of cultivated plants, especially violets, remain green through the winter and are well adapted to serve as winter hosts of

FIG. 7.—Portable barrel pump for application of herbicide to weed borders.

the red spider. Many cases of cotton infestation can be traced to near-by dooryards. The beds of violets and other plants should be thoroughly sprayed as soon as they show signs of infestation. The most satisfactory solution, where violets are concerned, consists in their removal or complete destruction.

HERBICIDES.

Certain chemical sprays can be applied to weed and plant borders, which kill them rather quickly. Of these, sodium arsenate, used at the rate of 1 pound to 20 gallons of water, is the most satisfactory. The ease and speed of destruction that accompany the use of such a remedy justify urging its use as a substitute for the old-fashioned

and tedious hoeing method. (See fig. 7.) It must be remembered, however, that sodium arsenate is a poison, and care should be taken to prevent horses and cattle from grazing on treated weeds.

SPACING.

Some have claimed that infestation spreads through a field only by means of the interlacing cotton branches, and that by increasing the spacing the spread of the red spider can be prevented. Since it is now known, however, that the mites commonly travel on the ground also, from plant to plant, it is easily seen that wide spacing of cotton plants will by no means entirely prevent the spread of the pest.

MAINTAINING MULCH.

By maintaining continually in fields a finely pulverized surface mulch the progress of migrating mites is somewhat retarded and the development of infestation correspondingly discouraged. The planting of cotton by the checking system permits the cultivation of each plant on four sides and is a good method from the viewpoint of the control of the red spider.

ROTATION.

Since the wild grasses and small grains appear to be about the only plants which are free from red-spider attack, there is little in the way of immune crops which can be used for the purpose of rotation. Furthermore, provided the sources of infestation were allowed to remain, the pest would surely reinvade fields, upon the return to cotton, even should the small grains or grasses be planted for a time.

FERTILIZERS.

Although the fertilizing of cotton land in no way discourages the development of red spiders, yet the judicious use of fertilizers invigorates the plants so that they are better fitted to overcome the injury.

REPRESSIVE MEASURES.

Under the heading "Repressive measures" may be discussed those measures which can be taken to combat the pest when it has gained entrance to cotton fields. It has been demonstrated that it is possible to eradicate the pest from infested fields.

By keeping a constant watch of cotton fields the earliest affected stalks may be detected and destroyed. In this method it is usually necessary to repeat the operation several times, since certain plants

are likely to be overlooked during the first inspection. Great care should be taken to locate every plant which shows infestation, and these must be taken from the field, without brushing against healthy plants, and burned immediately. If infestation has not advanced too far, the prompt application of this method is usually effective.

If infestation has spread until a considerable patch has become involved, more drastic steps are necessary than those just mentioned. Where a continuous area of infestation occurs in a large field, it is often advisable to plow up the worst affected portion and spray the rest of the infestation in order to save the balance of the field. The stalks should be quickly piled up and burned with the aid of straw or light trash. Such a severe measure should only

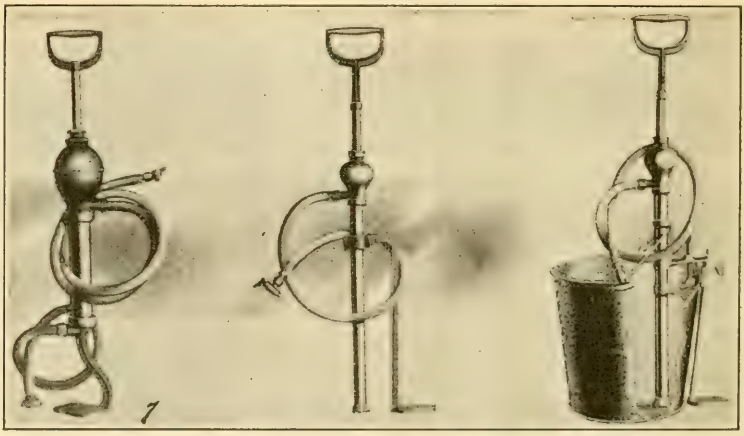

FIG. 8.—Bucket spray pump. (From Quaintance illustration.)

be resorted to in extreme cases, and the planter concerned must be the judge of its advisability.

INSECTICIDES.

Out of 75 different spray combinations tested against the red spider on cotton the following have been found to be thoroughly satisfactory: (1) Potassium sulphid (1 ounce to 2 gallons water); (2) lime-sulphur (homemade or commercial); (3) kerosene emulsion (prepared according to usual formula); (4) flour-paste solution (1 gallon stock paste to 12 gallons water). Spraying for the red spider is effective if it is done with extreme care. The foregoing sprays, when properly applied, kill all mites, but *a second spraying, one week later, is necessary to kill the individuals that were in the egg stage at the time of the first spraying.* Arsenical sprays are of no use against red spiders.

SPRAYING OUTFITS.

The sort of outfit to be used for spraying the red spider on cotton depends mainly on the extent of the occurrence. Many prefer to use a small tin atomizer when only a score or so of plants are to be treated. These instruments are very economical of liquid and throw a very fine, vapory spray which reaches all parts of the plants. The bucket pump (fig. 8) and knapsack pump (fig. 9) come into use in cases of considerable scattered infestation, or for treatment of a few plants in tall cotton where the platform pump would be undesirable. The most economic outfit for a severe case comprising several acres consists of a barrel pump carried through the field on a wagon or specially constructed vehicle of some sort. Figure 10 is from a photograph of a portable outfit used very successfully in demonstration work in North Carolina. It consists of a platform built upon the axle and shafts of a dismantled hayrake. The wheels are large, bringing the axle well above the ground, so that the vehicle does very little damage to the plants. Since the gauge of the outfit is 8 feet, it straddles two cotton rows, the single draft animal walking in the middle between these rows. A barrel pump with a capacity of 50 gallons is mounted on the platform. A boy drives, one man pumps, and two men handle the two sprayers. Thorough treatment of 4 acres per is readily obtainable with these devices.

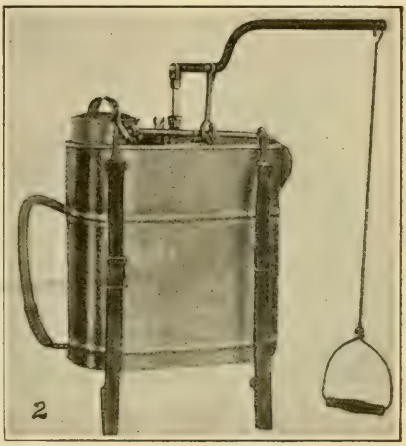

FIG. 9.—Knapsack sprayer. (From Quaintance.)

NECESSITY FOR THOROUGH SPRAYING.

Some dissatisfaction has been experienced among certain planters who have undertaken to check the ravages of the red spider by spraying. With pests which devour the entire leaf, such as potato "bugs," cotton caterpillars, etc., even the careless application of Paris green to the top of the foliage often proves entirely satisfactory. This is explained by the fact that pests of that kind are constantly moving from leaf to leaf and are sure to get some of the poisoned foliage. Also, since these insects usually eat completely through the leaf, it matters little upon which side the poison falls. With the red spider, however, it is very different. A contact insecticide is absolutely necessary, and since the mite spends its life on the underside of

a single leaf it is most important in spraying to *hit the entire underside of every leaf of an infested plant.* Careless spraying is certain to yield unsatisfactory results.

SUMMARY OF REMEDIES.

To prevent injury to cotton by red spiders the following steps should be taken: (1) Destruction of all weeds around the farm during the winter and early spring; (2) spraying of cultivated plants around the dwellings; (3) maintaining a finely pulverized surface soil; (4) destruction of early infested plants or large areas of heavy infestation by plowing up and burning; and finally (5) spraying with potassium sulphid, lime-sulphur, kerosene emulsion, or a flour-paste solution if the infestation is more or less general.

FIG. 10.—Ideal spraying outfit for treatment of considerable red-spider infestation.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 737 JUNE 26, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE CLOVER LEAFHOPPER[1] AND ITS CONTROL IN THE CENTRAL STATES.

By EDMUND H. GIBSON,

Scientific Assistant, Cereal and Forage Insect Investigations.

INTRODUCTION.

The control of the injurious clover leafhopper (fig. 1) is a comparatively simple task to one acquainted with the habits of the insect.

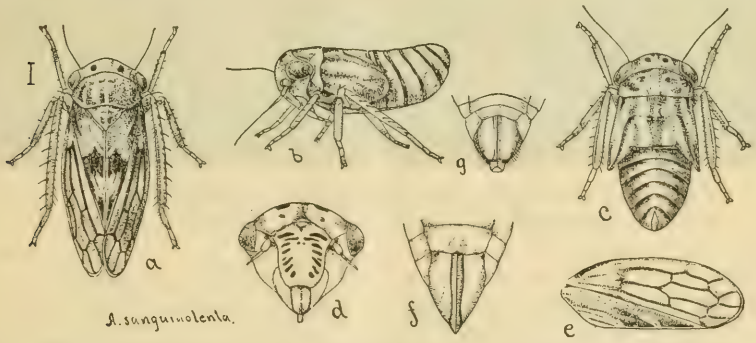

FIG. 1.—The clover leafhopper (*Agallia sanguinolenta*): *a*, Adult; *b*, nymph, side view; *c*, nymph, dorsal view; *d*, face; *e*, elytron; *f*, female genitalia; *g*, male genitalia. All enlarged. (After Osborn and Ball.)

The injuries caused by this insect, as is the case with many other leafhoppers, are often overlooked because of the minute size of the pest, and the apparent injury is too frequently attributed to such causes as poor soil and climatic conditions.

[1] *Agallia sanguinolenta* Prov.; suborder Homoptera, family Bythoscopidae.

NOTE.—It is the purpose of this bulletin to set forth such facts as will familiarize the farmer with the various stages in the development of the clover leafhopper, its habits, and mode of attack, together with detailed information as to the control of outbreaks in alfalfa and clover fields.

IMPORTANCE OF THE DAMAGE.

Each year this leafhopper, by lessening the vitality of its food plants, occasions more or less damage over its entire range of distribution, causing a positive, although not easily estimated, decrease in the clover and alfalfa hay crops of the country. Continued attacks often result in the loss of a considerable percentage of a single cutting; especially is this true in some of the central States. The leafhopper causes the greatest damage during the spring and early summer months, as the foliage is then most succulent and the tissues very tender, enabling even the immature leafhoppers readily to pierce the skin of leaf and stem and suck the juices. The incessant drain from concentrated attacks causes the clover plants to wither, and

FIG. 2.—A spot in an alfalfa field showing the spindling growth of the plants, caused by continued attacks of leafhoppers. (Original.)

although they may not die, the new growth which is put forth is very apt to be thin and spindling (fig. 2). With alfalfa it is the first two crops which appear to suffer most. The drain upon alfalfa plants does not show as markedly as with clover, especially during a drought, since the alfalfa roots go deeper into the ground and the plant is better able to withstand adverse conditions.

DESCRIPTION OF THE INSECT CAUSING THE DAMAGE.

In many localities these leafhoppers are commonly known as "flies," but in reality they resemble flies only in having wings, and because they are about the size of many small flies seen in the fields. The adult or parent insects (fig. 1, *a*) are light gray in color, but have numerous dark markings which give them a mottled appearance. They are about one-eighth of an inch in length and half as wide.

The face (fig. 1, *d*) is triangular and is marked with short black lines. The two small, round, dark spots on the upper side of the head distinguish the clover leafhopper from many others frequently observed in alfalfa and clover fields. The nymphs, or young, resemble the adults in form but lack wings. In color they are creamy white with heavy dark spots and bands. The eggs are white and very small. To the farmer, leafhoppers will be distinguished from other insects not so much by their form and markings as by their habit of jumping, their quick movements, and their minute size. The manner in which they jump from plant to plant is much like that of grasshoppers.

WHERE THE LEAFHOPPER OCCURS.

The clover leafhopper is distributed generally throughout the United States, records showing its occurrence in every section of the country. Its range also includes southern Canada and Mexico.

THE INJURY, AND HOW IT IS PRODUCED.

The primary injury is produced by the direct feeding of the leafhoppers. The single tiny feeding puncture is itself inconsequential, and injury results only when a great number of leafhoppers attack the same plant. As many as 600 have been counted upon one plant. The early stages of injury are indicated by a yellowing of the tissue around the feeding punctures. These spots gradually enlarge and become more pronounced, and the plants take on a sickly condition which results in the curling up of the leaflets and the final wilting of the foliage. The leafhoppers have been noted to puncture the flower buds and petals, and in this way to cause a decrease in the amount of seed produced. Upon grains, grasses, and grasslike plants most of the feeding is done along the midribs of the blades, causing the latter to shrivel.

A second form of injury is produced by the forcing of the eggs into the stem and leaf tissue by the adult female. This causes a distortion of the surrounding tissue and often results in a gall-like formation.

PLANTS ATTACKED.

The principal plants attacked are those of the bean family, including alfalfa, clover, cowpea, and vetch; although the species is common in meadow and pasture lands and feeds on a number of cultivated as well as native grasses. Adults have been captured in wheat, rye, and barley fields, but in all probability they migrated there from near-by grasslands or clover fields. The frequent occurrence of this leafhopper in wheat in the eastern half of the United States

is very probably due to the practice of planting wheat before the clover comes up in the spring. In some of the western States it has at times been considered a pest to sugar-beet plants.

As plants of one family constitute the principal food plants of this leafhopper, it is to be assumed that it has not the power of readily adapting itself to changes of food plants. The fact that the clover leafhopper occurs in grass and pasture lands and also feeds upon grain plants in the absence of clover or alfalfa during the winter and spring merely indicates that when its favorite plants are not obtainable it is forced to seek food elsewhere.

STAGES AND LIFE CYCLE OF THE LEAFHOPPER.

There are three general stages in the development and growth of all leafhoppers, namely, egg, nymph or immature stage, and adult. The adult female places her eggs in stems and leaves, these hatching in from 5 to 12 days during the summer months in the latitude of southern Illinois. The nymphs develop and increase in size by shedding their skins through a series of five molts, becoming adults after the last molt. The nymphal stage in the same latitude ranges from 18 to 35 days, with an average of 25 days.

NUMBER OF GENERATIONS IN A YEAR.

The number of generations of the leafhopper produced annually in a given locality varies from year to year, depending on weather conditions, and it also varies in different latitudes and climates. For southern Missouri and northern Arkansas there are usually three distinct broods, covering approximately (1) April and May, (2) June and July, and (3) August and September. Farther south or under subtropical conditions it is probable that there are four or more.

HOW THE LEAFHOPPER PASSES THE WINTER.

In the Northern States the clover leafhopper hibernates in the adult stage, at the base of clumps of grass and weeds and under dried leaves and trash. Throughout the Central and Southern States it could hardly be said to hibernate; instead, the adults merely keep in hiding and under cover during cold weather, coming out on warm days to bask in the sun and feed upon such green foliage as can be found. In Missouri, for example, the adult insects have been observed feeding upon wheat during January and February, but not in any abundance. Nymphs can not long survive cold weather, and it is not probable that eggs survive over winter. In the extreme Southwest, where conditions are radically different, the leafhopper is active throughout the entire year.

HABITS OF THE ADULT AND YOUNG LEAFHOPPERS.

The adults are quick of movement and jump from plant to plant when disturbed. When strong winds prevail they remain in hiding, as they seem to dislike windy weather. Their most characteristic habit is that of congregating in great numbers on one plant, frequently to such an extent that they crowd one another. This is what causes the concentrated attacks in "spots" throughout a field. The clover leafhopper does not seem to seek shady or damp places, rather preferring the heat of the midday sun.

The nymphs are much less active than the adults and are not easily disturbed. When one brushes against the plants they cling fast to the stems and leaves instead of jumping to another plant. Like the adults, they have the habit of crowding together along a stem or upon a leaf.

ENEMIES OF THE LEAFHOPPER.

The insect enemies of the clover leafhopper seem to be few. Birds appear to be the most important enemies, and among the common species known to eat various species of leafhoppers in numbers are the nuthatches, yellow warbler, blue-headed vireo, long-billed marsh wren, nighthawk, phoebe, tree swallow, cliff swallow, bank swallow, and chickadee. In addition to these, over a hundred species of wild birds are known to feed upon leafhoppers. These birds should receive protection at the hands of the farmer. Chickens, turkeys, and guinea fowl, when allowed to run in the clover and alfalfa fields, eat great numbers of both nymphs and adults. Many adults have been observed in spider webs, and it is very likely that in their jumping from plant to plant numbers are caught in the webs.

CONTROL OF THE LEAFHOPPER.

BURNING OF RUBBISH AND WASTE VEGETATION.

The burning of rubbish and vegetation during the winter months in waste places such as on ditch banks, on terraces used in certain sections for the prevention of erosion, and along fence rows and roadsides will do much to prevent the species from becoming destructive the following spring and summer, for if this is done, their winter quarters will be destroyed and great numbers of the leafhoppers, as well as many other hibernating insects, will be killed.

CLOSE CUTTING OR PASTURING OF GRASSLANDS; EARLY CUTTING OF ALFALFA.

Close cutting or pasturing of grasslands is recommended while the leafhopper is in the adult stage. Cutting the alfalfa crop from a week to ten days earlier than usual will often have the desired effect of checking the species, and is advised where there is evidence that the leafhoppers are causing sufficient injury to justify the risk of damage through premature cutting.

USE OF THE HOPPERDOZER.

For direct control the hopperdozer is recommended. Any hopperdozer which has been constructed to capture grasshoppers will suffice, but a much lighter and less expensive one can be made by stretching canvas over a light wooden frame. The diagram, figure 3, shows how it can be made. It is of such light weight that in pulling it over alfalfa and clover the plants are not injured. In pulling this hopperdozer through fields which are free from stones runners will not be necessary. It is drawn by two horses, one hitched at either end of the two-by-four, and is dragged over the crop, covering as much acreage in the same length of time as is gone over by a cutting or mowing machine. Figures 4 and 5 show the front and back of the hopperdozer ready to be drawn through an alfalfa field. It is to

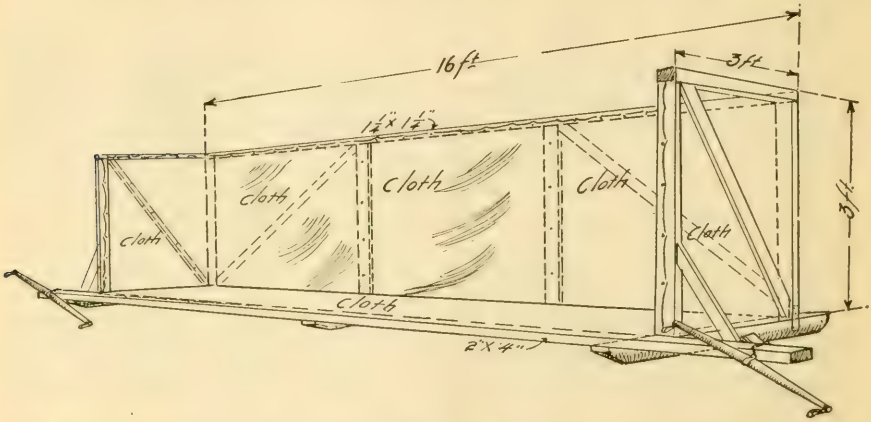

FIG. 3.—Construction of frame of hopperdozer for destruction of leafhoppers, over which canvas is stretched. (Original.)

be regretted that in figure 4 the bottom of the hopperdozer is not visible. Heavy canvas is stretched and tacked or nailed over the inside of the frame, covering bottom, back, and sides.

Over the canvas, on the inside, is applied a thin coat of a sticky substance made of tree tanglefoot which has been thinned with a cheap commercial grade of castor oil at the rate of 1 pound of tanglefoot to one-fourth pint of castor oil. This can be spread on the canvas with a paddle or shingle. The leafhoppers and other insects alighting on the sticky surface are held fast. These insects, together with dried leaves which will adhere to the canvas, can be scraped off whenever necessary and another coating of tanglefoot applied. One coating should be sufficient for 5 acres.

The cost of the hopperdozer should be little more than the price of the canvas, as odd pieces of lumber can be used in construction.

Tree tanglefoot can be obtained in 10-pound cans at $1.65 per can, and the castor oil at a maximum cost of 30 cents per quart. With-

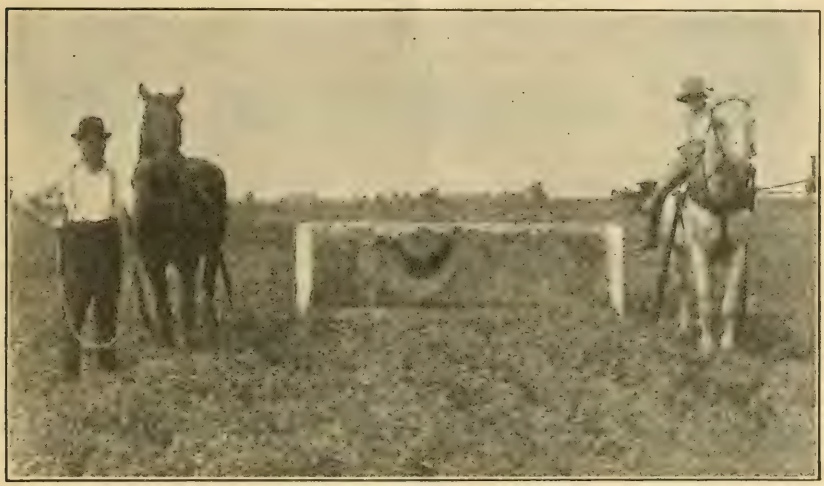

FIG. 4.—Front view of hopperdozer for destruction of leafhoppers as it is being drawn through an alfalfa field. (Original.)

out considering labor, the cost of this control measure should not be more than $4 for 100 acres, or at the rate of 4 cents per acre.

FIG. 5.—Side and back view of the hopperdozer for destruction of leafhoppers. The horses are hitched to the projecting ends of the two-by-four. (Original.)

This method is practical in fields covering several hundred acres as well as in small fields. Other sticky substances such as cheap sor-

ghum and corn sirup have been tried in place of tree tanglefoot but with much less success, as they dry out too quickly; this necessitates more frequent applications and thus renders them more expensive.

The hopperdozer should be drawn through the alfalfa and clover fields at the time when the crop is about half grown. It can, however, be drawn at any time without injuring the plants, although it is not advisable to do so within five days of the time the crop is to be cut. If the adults are numerous at the time of cutting, the hopperdozer should follow the rake.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 739 JUNE 1, 1916.

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

CUTWORMS AND THEIR CONTROL IN CORN AND OTHER CEREAL CROPS.

By W. R. WALTON and J. J. DAVIS,

Entomological Assistants, Cereal and Forage Insect Investigations.

IMPORTANCE AND NATURE OF CUTWORM INJURY.

Numerous complaints of the ravages of cutworms, especially in relation to corn, are received each season by the department. Prompt action is necessary for controlling cutworms after their presence becomes noticeable in the spring, which is usually about the time the corn begins to sprout. Because of the fact that the delay necessary between the time the worms make their appearance and the time a reply can be received from the department is often disastrous to the crop, the importance of recognizing these insects and knowing how to control them is evident.

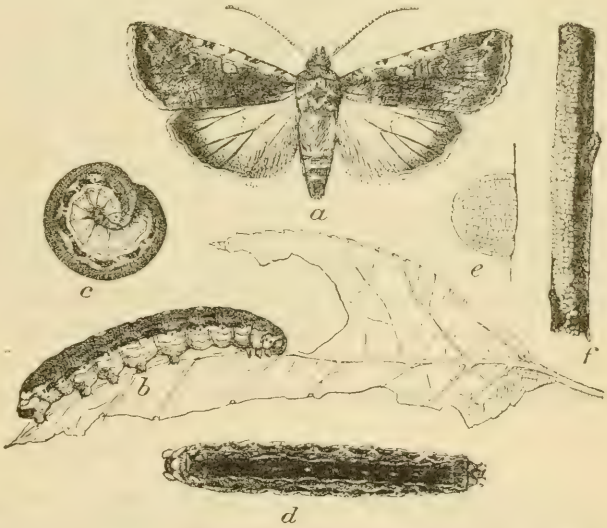

FIG. 1.—Variegated cutworm (*Peridroma margaritosa*): *a*, Moth; *b*, normal form of caterpillar, side view; *c*, same in curved position; *d*, dark form, view of back; *e*, greatly enlarged egg, seen from side; *f*, egg mass on twig. (From Howard.)

Cutworm injury almost invariably occurs in the spring, the plants usually being cut off at the surface, or a little below the surface, of the ground, beginning as soon as the first plants sprout and continuing until late June or early July, by which time the worms are full grown. Feeding takes place at night, the worms resting during the day beneath débris or in the soil at a depth of from one-half to 1 inch below the surface, and since they closely resemble the color of the soil in most cases, the cause of the injury is often not apparent. However, if the soil surrounding the cut-off plant be examined carefully, the culprit will quite likely be found curled up in the soil as illustrated (fig. 1, *c*).

LIFE HISTORY OF CUTWORMS.

The various cutworms are known under a number of popular names, such as the glassy cutworm, greasy cutworm, variegated cutworm, clay-backed cutworm, etc., but the injuries caused by them are very similar and their habits in general are also much the same. The parents of cutworms are grayish or brownish moths or "millers," which commonly occur at lights during summer evenings. Each moth may lay from 200 to 500 eggs, either in masses or singly, in fields covered with dense vegetation, and hence are to be found more often in cultivated fields which have been in grass or weeds the preceding fall. The eggs hatch in the fall, a few weeks after they are laid, usually during September, and the young cutworms, after feeding on grass and other vegetation until cold weather, pass the winter as partly grown caterpillars. If such infested fields are left to grass, no noticeable injury is likely to occur, but when it is broken up and planted to corn or other wide-row crops, the worms, being suddenly placed on "short rations," wreak havoc with the newly planted crops, the nearly full-grown worms feeding greedily and consuming an enormous amount of food. In northern latitudes they attain full growth and stop feeding in late June or early July, and change to the pupal or resting stage. The injury often ceases so suddenly that farmers are at a loss to account for the fact.

CONTROL OF CUTWORMS.

Land to be planted to corn the following spring, especially such land as has laid in grass for a considerable time and is likely to contain cutworms, should be plowed in midsummer or early fall about the time the eggs are laid, or better, before the eggs are laid, for then vegetation which is suitable for the moths to lay their eggs upon is removed. The earlier the preceding year grasslands to be planted to corn are plowed, the less will be the probability that the

cutworm moths will have laid their eggs thereon, and the less, consequently, will be the danger of injury by cutworms the following year.

Late fall and winter plowing of grasslands, although not as effective as early plowing, will destroy many of the hibernating cutworms, as well as such other important corn pests as white grubs, and should be practiced when earlier plowing is impracticable.

Pasturing hogs upon land supposed to harbor cutworms is a beneficial practice, as these animals root up and devour insects of many kinds, including cutworms, in large numbers. Farm poultry, if trained to follow the plow, will prove of inestimable value.

When cutworms are found to be abundant on corn land, the use of the poisoned bait is recommended. This may be prepared as follows: Mix 50 pounds of wheat bran, 2 pounds of Paris green, and 6 finely chopped oranges or lemons. Then bring the whole mixture to the consistency of a stiff dough by the addition of a low-grade molasses, such as is used in cattle rations, adding water when necessary. Distribute this bait over the infected field in small lumps, taking care to sprinkle it sparingly around each hill. In case bran can not be readily obtained, middlings or alfalfa meal may be successfully substituted. In fields known to be infested, the distribution of this bait should be started as soon as the corn begins to appear above ground so that the cutworms may be eliminated as quickly as possible and the injured hills promptly replanted. During the warmer spring months cutworms do most of their feeding at night and burrow into the soil to the depth of an inch or two during the day, so that the bait will usually be more effective if applied during the late afternoon or early evening hours.

Frequently cutworms migrate to cultivated fields from adjoining grassland, and in such cases the crops can be protected by running a narrow band of the poisoned bait around the edge of the field or along the side nearest the source of infestation.

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE RELATING TO INSECTS INJURIOUS TO CEREAL AND FORAGE CROPS.

AVAILABLE FOR FREE DISTRIBUTION.

Cotton Bollworm. (Farmers' Bulletin 290.)
Common White Grubs. (Farmers' Bulletin 543.)
The Chalcis-fly in Alfalfa Seed. (Farmers' Bulletin 636.)
The Grasshopper Problem and Alfalfa Culture. (Farmers' Bulletin 637.)
The Hessian Fly. (Farmers' Bulletin 640.)
Alfalfa Attacked by the Clover-root Curculio. (Farmers' Bulletin 649.)
The Chinch Bug. (Farmers' Bulletin 657.)
Wireworms Destructive to Cereal and Forage Crops. (Farmers' Bulletin 725.)
The True Army Worm and its Control. (Farmers' Bulletin 731.)
The Hessian Fly Situation in 1915. (Office of Secretary Circular 51.)
The Spring Grain Aphis or "Green Bug" in the Southwest and the Possibilities of an Outbreak in 1916. (Office of the Secretary Circular 55.)
Southern Corn Rootworm, or Budworm. (Department Bulletin 5.)
Western Corn Rootworm. (Department Bulletin 8.)
The Oat Aphis. (Department Bulletin 112.)
The Alfalfa Caterpillar. (Department Bulletin 124.)
Clover Mite. (Entomology Circular 158.)
Clover-root Curculio. (Entomology Bulletin 85, pt. III.)
Maize Billbug. (Entomology Bulletin 95, pt. II.)

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The Larger Corn Stalk-borer. (Farmers' Bulletin 634.) Price, 5 cents.
The Southern Corn Leaf-beetle. (Department Bulletin 221.) Price, 5 cents.
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The Pea Aphis with Relation to Forage Crops. (Department Bulletin 276.) Price, 15 cents.
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Some Insects Affecting Production of Red Clover Seed. (Entomology Circular 69.) Price, 5 cents.
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Leafhoppers Affecting Cereals, Grasses, and Forage Crops. (Entomology Bulletin 108.) Price, 20 cents.
Spring Grain-aphis or Green Bug. (Entomology Bulletin 110.) Price, 25 cents.
Preliminary Report on Alfalfa Weevil. (Entomology Bulletin 112.) Price, 15 cents.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1916

UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 740 JULY 8, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

HOUSE ANTS: KINDS AND METHODS OF CONTROL.[1]

By C. L. MARLATT,
Entomologist and Assistant Chief.

CONTENTS.

INTRODUCTION.

There are now in North America a considerable number of species of ants which under favoring conditions may inhabit dwelling houses or other heated buildings, constructing their nests and breeding continuously in the woodwork or masonry, or in articles of furniture or of ornament, and subsisting on food materials which they find about kitchens and pantries or scattered in living rooms. Other species nesting in gardens and lawns or under adjacent walks may occasionally enter houses as foragers or as accidental guests.

It is interesting to note that, of the ants which in North America frequent houses and construct their nests therein, practically all are of tropical origin, and most of them are Old-World species.

[1] The authority for the scientific names and the source of many records of the less well-known house ants given in this bulletin is the notable work on American ants by Dr. W. M. Wheeler, entitled "Ants: Their Structure, Development, and Behaviour" (1910). Dr. Wheeler has also read the text of this bulletin and furnished some notes not available in print.

It is a matter of further interest that, with the exception of the European meadow ant, practically all of the ants which have been introduced into North America, either from the Old World or from South America, are such tropical species and potential house pests. All of these introduced species have been brought to North America and many of them given cosmopolitan distribution through the agency of commerce. The tropical ants in their native countries are still normally outdoor species, although in the Tropics they also frequent human habitations, including ships, and, by colonizing in ships' cargoes, are easily given world-wide distribution. Some of

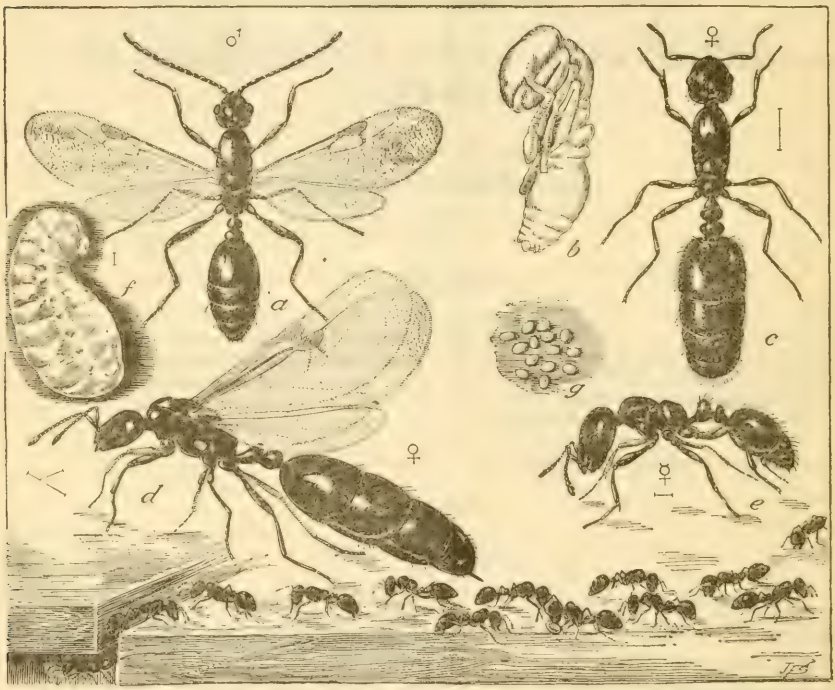

FIG. 1.—The little black ant (*Monomorium minimum*): *a*, Male; *b*, pupa; *c*, female; *d*, same with wings; *e*, worker; *f*, larva; *g*, eggs; group of workers in line of march below. All enlarged, the lettered illustrations all drawn to the same scale. (Original.)

these Old-World species have become established as out-of-door species in the New-World Tropics, but in temperate regions they are able to survive only in dwellings, hothouses, mills, or other structures where the requisite warmth is maintained. The ability of these imported tropical species to maintain themselves is largely due to the protection from competition with our native species afforded by this house-dwelling habit.

None of these ants, with the exception, in rare instances, of the carpenter ant, are so destructive to household effects or supplies as they are annoying from the mere fact of their presence and their

faculty of "getting into" articles of food, particularly sugars, sirups, cakes, candies and other sweets, and cooked foods of animal origin. Having once gained access to articles of this sort, the discovery is at once reported to the colony, and in an incredibly short time the premises may be swarming with these unwelcome visitors.

KINDS OF NORTH AMERICAN HOUSE ANTS.

The different kinds of North American house ants may be grouped on the basis of origin as follows: (1) Tropical Old-World ants, represented by 12 species; (2) ants introduced from the New-World Tropics, represented by 5 species; (3) native North American ants of temperate regions which occasionally inhabit dwelling houses, represented by 2 species; and (4) such occasional garden and lawn ants as may from time to time become accidental house pests by extending their forays into dwelling houses in quest of food, of which 4 native North American species are discussed, and also the introduced European meadow ant.

INTRODUCED TROPICAL OLD-WORLD ANTS.

The little red ant,[1] or Pharaoh's ant (fig. 2), is the best known house species. It has attained a thoroughly cosmopolitan distribution and has been domesticated so long that it is now difficult to determine its exact origin, except to place it generally in the Old-World Tropics. It was originally a soil ant, nesting out of doors in warm countries, and doubtless continues this habit in the tropics of both hemispheres. In temperate regions it passes its entire existence in heated houses.

Three other species of the same genus of Old-World tropical ants are recorded as having been brought to our shores and as having gained foothold, occasionally in dwellings.[2] None of these species have, however, so far established any important record in this country as house pests, although they may be expected to appear at any time in dwelling houses and other heated structures, particularly in the southern United States, and possibly farther north along the Atlantic seaboard. One of these, *Monomorium salomonis*, is stated to be the most abundant of North African ants, and to have been widely distributed by commerce and to occur in most tropical and subtropical countries. A native species of the same genus,[3] known as the little black ant, is referred to elsewhere.

Two Old-World agricultural or harvester ants[4] have been brought to this country by commerce and are now fairly well established in

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[1] *Monomorium pharaonis* L.

[2] *Monomorium salomonis* L., *Monomorium destructa* Jerdon, and *Monomorium floricola* Jerdon.

[3] *Monomorium minimum* Buckley.

[4] *Solenopsis geminata* Fab. subspecies *rufa* Jerdon and *Pheidole megacephala* Fab.

tropical America, and are potential house pests. One of these, *Pheidole megacephala*, was formerly the important house ant of Madeira, occurring in prodigious numbers throughout the southern portion of the island and up to an elevation of 1,000 feet, nesting out of doors under nearly every stone, and in houses generally. It is stated also that this ant is very common in the Bermudas and West Indies and will probably be found in Florida, and that wherever it gains foothold in subtropical countries it is able to propagate very rapidly and

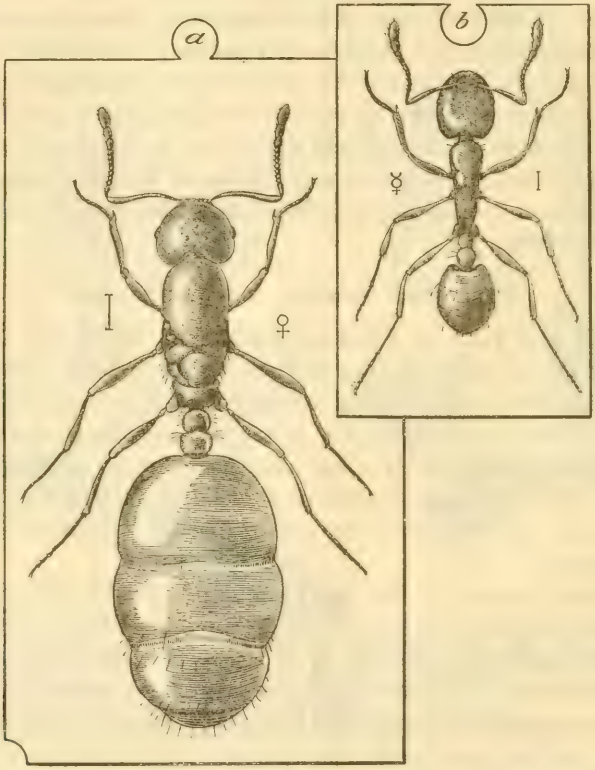

FIG. 2.—The little red or Pharaoh's ant (*Monomorium pharaonis*); *a*, Queen or female; *b*, worker. Both drawings enlarged to the same scale. (Original.)

to exterminate the indigenous ant fauna; in fact, several instances of this kind have been noted. This ant, on the other hand, has itself lately been driven out and practically exterminated in Madeira by the Argentine ant,[1] which latter ant has also, in New Orleans and elsewhere in the United States, similarly displaced our native ants. As North American house ants, however, neither of these Old-World harvester ants has so far assumed any importance, although both probably occur in Florida.

[1] *Iridomyrmex humilis* Mayr.

Six other Old-World tropical ants have been recorded as introduced house-infesting species in North America.[1] These, like other Old-World ants, have been brought in through the agency of commerce and have gained foothold in tropical America and are occasionally found nesting in hothouses and other heated structures in temperate regions.

One of these ants, *Prenolepis longicornis*, a slender, black species with unusually long legs and antennæ or "feelers," has earned the common name of "crazy ant" from its habit of running about, usually singly and apparently aimlessly, with a quick, jerky motion. This ant has long been a common species in the greenhouses of temperate Europe and America, and in some of these, as in the Jardin des Plantes in Paris, it has been a permanent resident for more than 40 years. It has acquired a footing in tropical Florida, and probably also in other localities in the Gulf States, and has been reported as infesting, even to the top floors, large apartment build-

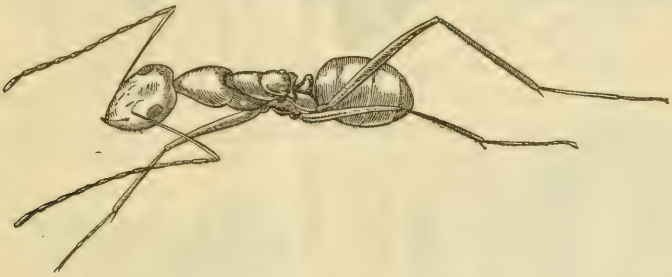

FIG. 3.—An introduced tropical Old-World ant. *Plagiolepis longipes*. Enlarged. (After Wheeler.)

ings in New York City, and also as occurring in hotels and flats in Boston. It is a common house ant in the District of Columbia. India is believed to be the original home of this ant, whence it has been carried to all tropical countries in ships, and it has been accompanied in its wanderings by three insect messmates, namely, two beetles and a small cricket.

A related species, *Prenolepis vividula*, is a common greenhouse pest in Europe and is reported as having been found in greenhouses in this country; in one instance as far north as Canada. Another of these Old-World ants, *Plagiolepis longipes* (fig. 3), will probably ultimately come into prominence as a house species on this continent. Its original home is given as Cochin China, but it has already established a foothold in widely separated parts of the world. On the island of Reunion, for example, it is very abundant and is reported to be driving out some of the primitive species. It has also been recorded on this continent from Todos Santos, Lower California.

[1] *Tetramorium guineense* Fab., *Tetramorium simillimum* Roger, *Tapinoma melanocephalum* Fab., *Prenolepis longicornis* Latr., *P. vividula* Nyl., and *Plagiolepis longipes* Jerdon.

INTRODUCED TROPICAL NEW-WORLD ANTS.

Of the ants introduced into North America from the New-World Tropics the one of greatest economic importance is what has now come to be generally known as the Argentine ant (fig. 4)[1] from its supposed Argentine origin. It is known, however, to be a serious pest in Brazil and Uruguay, as well as in Argentina. It is sometimes also called the New Orleans ant, from the fact that it gained its first foothold from colonies brought in, presumably from Brazil,

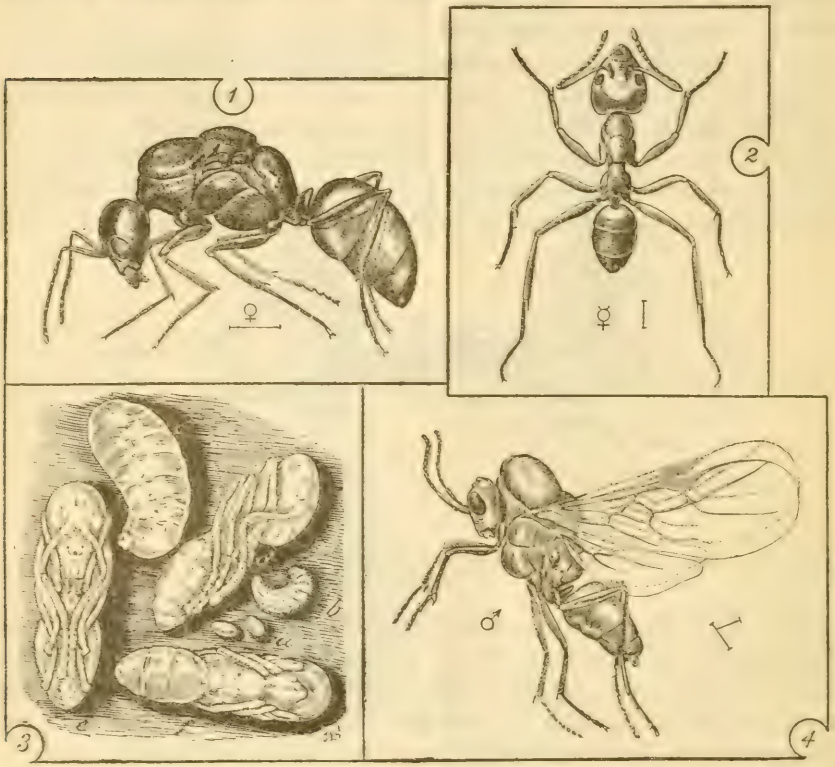

FIG. 4.—The Argentine ant (*Iridomyrmex humilis*). *1*, Wingless female. *2*, Worker. *3*, Immature stages: *a*, Eggs; *b*, young larva; *c*, full-grown larva; *d*, pupa, side view; *e*, pupa, ventral view; *f*, pupa, dorsal view. *4*, Male. All enlarged to the same scale. (Original.)

by some ships' cargoes to the port of New Orleans. It is a much worse house pest than even the little red ant or any of the other house ants and is in addition a very serious enemy of field and garden crops and orchard trees. It has rapidly spread from the point of introduction throughout Louisiana and has been carried by traffic to California, where it has become a serious pest in citrus orchards in the southern part of the State, and in houses as far north as San Francisco. It is undoubtedly destined to extend its outdoor range

[1] *Iridomyrmex humilis* Mayr.

wherever climatic conditions permit and as a house and greenhouse pest over a much wider area. Its rôle as an exterminator of native ants in the New Orleans district and in the island of Madeira has already been referred to. It is the only one of the imported tropical ants which causes any large monetary losses. The other species, as elsewhere noted, are for the most part merely annoying.

Four other species of ants from tropical America have gained, through the agency of commerce, some foothold as house pests in the southern and eastern United States, and manage to live for considerable periods of time in northern heated houses.[1]

One of these, *Prenolepis fulva* subspecies *pubens*, has been recorded from the District of Columbia, where it was found infesting one of the hothouses of the Department of Agriculture. It is believed to be a native of Brazil, but now occurs quite abundantly in Cuba and other West Indian Islands. It is still a comparatively rare house pest, however, in temperate regions of North America, and, except in the Tropics, undoubtedly can not survive outside of heated buildings.

NATIVE NORTH AMERICAN ANTS OF TEMPERATE REGIONS.

Only one North American ant of temperate regions has become a true house dweller and pest. This distinction belongs to the little "thief ant,"[2] a native of our Northern and Eastern States. The workers of this ant are very small, and yellowish in color. They frequently, as do also Old-World species of the genus, inhabit the gallery walls of other and larger ants, where they are apparently unnoticed, and kill and eat the helpless larvæ and pupæ of their apparently unconscious hosts. The thief ant may, however, lead an independent existence, and has been reported as a frequent pest in dwellings. It feeds on any animal matter, including dead insects, and has been recorded as attacking the sprouting kernels of Indian corn. This species can be readily distinguished from the little red, or Pharaoh's, ant by its much lighter color and smaller size.[3] This species is reported by C. H. Popenoe, of the Bureau of Entomology, United States Department of Agriculture, as nesting in houses very much as does the little red ant, colonies of the thief ant having been found, for example, in an envelope, and again in a box of photographic dry plates.

The carpenter ant[4] (fig. 5) should be considered in the list of house ants, although perhaps only accidentally, and under exceptional circumstances, a house-infesting species. The carpenter ant of North America, a subspecies or variety of the European and Asiatic

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[1] *Prenolepis fulva* Mayr subspecies *pubens* Forel, *Neoponera villosa* F. Smith, *Camponotus abdominalis* Roger subspecies *floridanus* Buckley, and *Pheidole flavens* Roger subspecies *floridanus* Emery.

[2] *Solenopsis molesta* Say.

[3] It is further distinguished by the possession of very rudimentary eyes, and a two-jointed instead of three-jointed "club" to the antennæ.

[4] *Componotus herculeanus* L., subspecies *pennsylvanicus* De G.

species of the same name, is dark brown or black in color, and is the largest of the house-frequenting ants, the workers varying from one-fourth to one-half inch in length and the winged female attaining a length of nearly an inch. It normally constructs its galleries in logs and dead trees in forests, but not infrequently, in the case of wooden houses, and especially those in or near forested tracts, gains access through porch beams or the underpinning of such houses and mines and weakens the supporting timbers and other woodwork. As a rule it affects only the decaying portions of the wood, but sometimes carries its channels into the sound wood. Many instances of damage of this sort have been reported, possibly some of them,

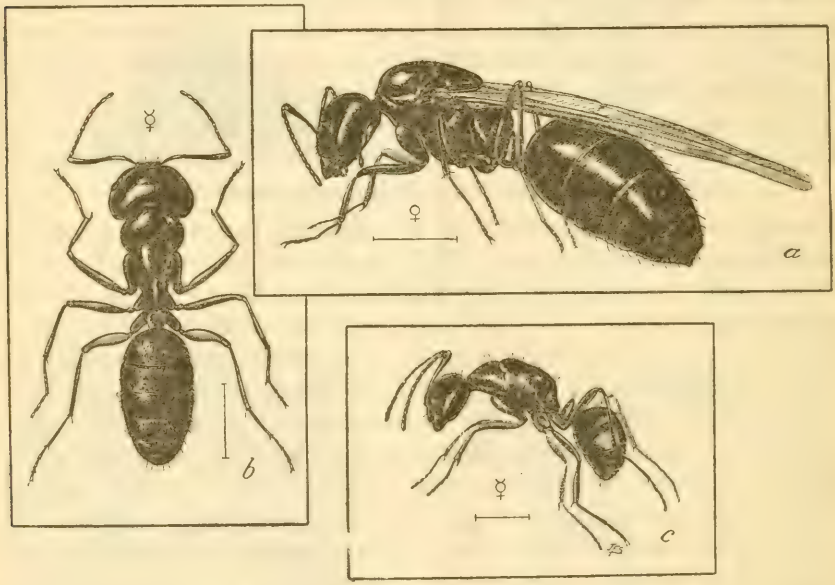

FIG. 5.—The carpenter ant (*Camponotus herculeanus pennsylvanicus*): *a*, Winged female; *b*, worker major; *c*, worker minor. All enlarged to same scale. (Original.)

however, due to confusion of the work of this ant with that of the common termite or so-called white ant.[1]

GARDEN AND LAWN ANTS AS HOUSE PESTS.

Almost any of the common garden or lawn ants which build their little crater nests in lawns or in soil about houses may become temporarily or on occasion house pests in their search for food substances. Four native ants and one introduced species have achieved notoriety in this way.[2] One of these, referred to in earlier circulars issued by this department on house ants as the little black ant[3]

[1] *Leucotermes flavipes* Kollar.

[2] *Monomorium minimum* Buckley, *Lasius niger* L. var. *americanus* Emery, *Prenolepis imparis* Say, and *Formica fusca* L. var. *subsericea* Say.

[3] *Monomorium minimum* Buckley.

(fig. 1), is essentially a lawn or meadow ant, and its entrance into houses is due to chance or accident. Its small nests, with the opening surrounded by its protecting wall of fine grains of soil, can be frequently noted in lawns, and if these nests are opened the colonies will be found to consist of workers, with one or more much larger gravid females. When these or other lawn ants gain access to houses, attracted by food supplies, the nuisance can often be eliminated by tracing them back to their outdoor colony and destroying the latter, as hereinafter described.

Perhaps the most abundant and widespread lawn or garden ant is a small yellowish-brown species which may be given the common name of the American lawn ant.[1] Its crater nests are exceptionally abundant throughout the Northern States, and not infrequently a dozen or more nests may occur on a square yard of lawn surface. In addition to the fact that it occasionally gains entrance to houses and becomes annoying as a depredator on larder supplies, it is a lawn and garden pest of some importance; and, furthermore, has the reputation of hoarding over winter the eggs of aphids and colonizing the young aphids in the spring on their host plants, thus becoming a very important factor in increasing the damage to garden and field crops by these injurious insects. In the case of lawns and meadows, aside from the harboring of injurious aphids, direct injury from this ant is probably negligible, or is offset by the actual benefit which may result from the bringing up of its little craters of sand and earth to form a sort of top dressing or soil mulch. The other two native garden and lawn ants have similar habits.

In this same class of outdoor ants which may occasionally find entrance into houses should be included the common European meadow ant,[2] one of the few Old-World ants of temperate regions which has been brought to America. This ant has readily accommodated itself to conditions of urban existence in the eastern United States, and its colonies occur in lawns and often under pavements, or beneath flagging or stones in yards. These colonies are often large and may frequently be uncovered in masses of a quart or more, on turning over stones in yards or lifting flagging in paths.

HABITS AND LIFE HISTORY OF HOUSE ANTS.

In habits and life history these ants are all much alike and, in common with other social insects, present that most complex and interesting phase of communal life, with its accompanying division of labor and diversity of forms of individuals, all working together in the most perfect harmony and accord. The ants ordinarily seen in houses are neuters or workers. In the colony itself, if it be discovered and opened, will be found also the larger wingless females and,

[1] *Lasius niger* L. var. *americanus* Emery.
[2] *Tetramorium caespitum* L.

at the proper season, the winged males and females. During most of the year, however, the colony consists almost exclusively of workers, with one or more perfect wingless females. Winged males and females are produced during the summer and almost immediately take their nuptial flight. The males soon perish, and the females shortly afterward tear off their own wings, which are but feebly attached, and set about the establishment of new colonies. The eggs, which are produced in extraordinary numbers by the females or "queen" ants, are very minute, oval, whitish objects, and are cared for by the workers, the young larvæ being fed in very much the same way as in the colonies of the hive bee. The so-called ant eggs, in the popular conception, are not eggs at all, but the white larvæ and pupæ, and those of females or males are much larger than those of the workers and many times larger than the true eggs.

MEANS OF CONTROLLING HOUSE AND LAWN ANTS.

DESTRUCTION OF HOUSE COLONIES.

The distinctively house-inhabiting ants, such as the little red or Pharaoh's ant, and other imported species nesting in the woodwork, masonry, or articles of furniture, etc., are often very difficult to eradicate because of their inaccessibility. If the nest can be located by following the workers back to their point of disappearance, the inmates of the nest, if near by, may sometimes be reached by injecting a little bisulphid of carbon, kerosene, or gasoline into the opening by means of an oil can or small syringe. *In the use of these substances, naturally, precautions should be taken to see that no fire is present, as all of them are inflammable.* If the nest is under flooring it may sometimes be gotten at by removing a section; but, as a rule, unless the colony can thus be reached and destroyed other measures are of only temporary avail if food or other conditions continue to attract the ants and facilitate their continued breeding in the house.

The removal, therefore, of the attracting substances in houses, wherever practical, should be the first step. Ants are attracted by food material, especially cake, bread, sugar, meat, and like substances, in pantries and elsewhere, and the nuisance of their presence can be largely limited by promptly cleaning up all food scattered by children and by keeping in the pantry or storeroom all food supplies which may attract ants, in ant-proof metal containers or in ice boxes, and limiting the amount of such articles as far as possible to daily needs.

That it is possible to drive ants away from household supplies by the use of repellents, particularly camphor and naphthalene flakes or powdered moth balls, has been asserted. The use of most of such repellent substances, however, in connection with food supplies, is impracticable, and careful tests have indicated that such substances

have only slightly repellent properties and bring comparatively little benefit.

The collection of ants by the use of attractive baits is frequently recommended. Perhaps as convenient a bait as any consists of small sponges moistened with sweetened water and placed in situations where they can be easily reached by the ants. These sponges may be collected several times daily and the ants swarming on them destroyed by immersion in hot water. It is reported also that a sirup made by dissolving borax and sugar in boiling water and distributed on sponges will effect the destruction of the ants in numbers. Remedies of this kind, however, are of doubtful value. They may be useful at the outset when the colonies are few and small and when most of the individuals may, by these means, be secured and destroyed. Very frequently, however, the distribution of such baits will simply result in a more wide exploitation of a good forage ground and an actual increase of the ant nuisance.

A more efficient remedy, where it can be safely used, is a sirup poisoned with arsenate of soda, the idea being that the ants will collect this poison sirup and convey it to their nests, so that not only the ants which collect the sirup are ultimately killed, but the inmates of nests feeding on it also succumb. The formula for the preparation of this sirup is as follows: One pound of sugar dissolved in a quart of water, to which should be added 125 grains of arsenate of soda. The mixture should be boiled and strained, and on cooling is used with sponges, as already described. The addition of a small amount of honey is said to add to the attractiveness to ants of this mixture. *Naturally the greatest precautions should be taken in preparing this sirup and in safeguarding it afterwards to prevent its being the cause of poisoning to human beings or domestic animals.* This method of control has been tested for three years by an expert[1] of the Bureau of Entomology of this department and has given very satisfactory results. Similar success with it has been reported by others, including persons engaged professionally in insect extermination. A related formula experimentally worked out for the Argentine ant will appear in a special bulletin on this insect.[2] This formula is as follows:

Granulated sugar	15 pounds.
Water	7½ pints.
Tartaric acid (crystallized)	¼ ounce.

Boil these ingredients together slowly for 30 minutes and allow them to cool. Then slowly dissolve three-fourths ounce sodium arsenite ($NaAsO_2$) in one-half pint of hot water. Allow this to cool, then add it to the sirup, stirring thoroughly. Add 1½ pounds of pure honey to the sirup and the mixture is ready for use.

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[1] C. H. Popenoe.

[2] Barber, E. R. The Argentine ant: Distribution and control. U. S. Dept. Agr. Bul. 377.

DESTRUCTION OF LAWN ANTS.

In the case of lawn ants where only a small area with few nests are concerned, drenching the nests with boiling water or injecting a small quantity of kerosene or coal oil will be effective, and similar treatment will apply to nests between or beneath paving stones.

Another simple means of destroying such ants in lawns of small extent is to spray the lawns with kerosene emulsion (see Farmers' Bulletin 127) or with a very strong soap wash, prepared by dissolving any common laundry soap in water at the rate of from half a pound to a pound of soap to the gallon of water.

An effective control method for larger ant colonies is to inject into the nest a quantity of bisulphide of carbon, a chemical which can be purchased at any drug store. This substance can be placed in the nest with an oil can or small syringe, the quantity varying from half an ounce for a very tiny nest to 2 or 3 ounces or more, depending on the size of the nest. An oil can or syringe with a long spout is convenient for this purpose, as this can be inserted into the nests and the liquid injected without its being too near the operator's nose. To facilitate entrance of the chemical, the ant hole can be enlarged with a sharp stick or iron rod. The depth of the injection will depend on the size of the nest—from an inch or two to greater depths. After injection of the bisulphide of carbon the entrance opening should be closed by pressure of the foot to retain the bisulphide, which will then penetrate slowly throughout the underground channels of the nest and kill the inmates. The efficiency of this remedy is increased by covering the nest immediately after the injection with a wet blanket or other heavy cloth, to better retain the fumes of the chemical. Bisulphide of carbon has a very disagreeable odor, but its fumes are not poisonous to higher animals. *As already noted, it should be kept away from fire, as its fumes are inflammable and may explode if ignited, much like gasoline vapor.*

PROTECTION FROM THE CARPENTER ANT.

The method of protection from damage by the carpenter ant is practically the same as that employed to protect from termites,[1] namely, preventing the ants from gaining access to foundation timbers by using in the foundations only timbers which have been previously impregnated with creosote. Ants infesting house timbers which have not been so protected may sometimes be reached and killed by the abundant use of kerosene injected by means of a syringe or, where the timbers are accessible, by spraying or soaking them with kerosene. All timbers which have been mined and weakened should, however, be replaced with timbers protected with creosote.

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[1] A special publication on white ants (Department Bulletin No. 333, prepared in the Bureau of Entomology) has been issued by the Department of Agriculture and may be had on application.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 741 JULY 17, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE ALFALFA WEEVIL AND METHODS OF CONTROLLING IT.[1]

By GEO. I. REEVES and PHILIP B. MILES, *Entomological Assistants*, and THOMAS R. CHAMBERLIN, STERLING J. SNOW, and LUTHER J. BOWER, *Scientific Assistants, Cereal and Forage Insect Investigations.*

INTRODUCTION.

The alfalfa weevil destroys a great deal of alfalfa in northern Utah and southern Idaho. It also inhabits southwestern Wyoming and is spreading slowly to new territory in all directions. It may in time infest most of the United States. The adult (fig. 1), a small brown snout-beetle, and the larva (fig. 2), a green, worm-like creature, usually escape notice during the first two or three years that they are present in a locality, but as soon as they become numerous enough to do harm they are readily found, and their effect upon the appearance of the fields is conspicuous. Vigorous treatment is then necessary to prevent partial or total destruction of the first and second crops. The purpose of this bulletin is to show how serious the attack is to the farmer, how much territory it embraces and how it spreads, and to describe the insect, its work, and the methods which are effective in dealing with it.

FIG. 1.—The alfalfa weevil: Adult. Enlarged. (Original.)

[1] *Phytonomus posticus* Gyll.; order Coleoptera, family Curculionidae.

NOTE.—This bulletin describes the work and spread of the most dreaded pest of alfalfa in the United States. It is of interest in the region west of the Mississippi River, particularly Utah and the adjacent States.

IMPORTANCE OF THE ALFALFA WEEVIL AS A PEST.

This insect attacks Utah's most important crop. Alfalfa furnishes 80 per cent of the value of the hay and forage of the State, which in turn is 40 per cent of the value of all crops. The 1909 crop was worth nearly $6,000,000.[1]

About one-half of the annual yield is harvested in the first cutting and about one-third in the second. The damage to the first cutting ranges from slight depreciation of the quality of the hay to almost total loss, varying according to the rate of growth and the time of harvest; it may be estimated at 50 per cent. The damage to the second cutting, if no effort is made to prevent it, amounts to total loss. The menace to this State, therefore, involves one-half the yield, worth $3,000,000.

FIG. 2.—The alfalfa weevil (*Phytonomus posticus*): Larva. Much enlarged. (Original.)

Besides the loss represented by these figures, there is a less tangible but equally serious effect due to the peculiar relation of alfalfa to western agriculture. Because of its ability to revive after prolonged drought, to produce abundant crops for many years without reseeding, and to furnish a nearly complete ration for live stock, it has a very great value for a region where the water supply is scanty, reseeding expensive and difficult, and live stock an important and increasing source of wealth.

THE INFESTED DISTRICT.

The infested district (fig. 3) reaches north from Salt Lake City to Rosette, Utah; Strevell, Malad City, and St. Charles, Idaho; and Cokeville and Granger, Wyo. It extends south to Moroni and Oasis, Utah. These points lie near the rim of a circle about 100 miles from Salt Lake City. Eastward the weevil has gone only about 50 miles to the Uinta Mountains and westward an equal distance to the Salt Lake Desert.

SPREAD OF THE WEEVIL.

Both the outline of the infested district and the history of the spread show an average seasonal advance of about 10 miles per year since 1904 or 1905, when the insect was discovered by farmers at Salt Lake City. There are no isolated colonies distant from the main body, and there have been no long jumps in the movement. If wagons and railroad trains have carried weevils it has evidently been only for short distances. As has been predicted,[2] their spread has been largely by crawling and flight. The greatest progress has been along

[1] Thirteenth United States Census.

[2] Utah Agricultural College Extension Department Bulletin No. 1, 1909.

certain wagon roads, rather than in the direction of prevailing winds, railroads, or streams. This point is well illustrated by the road to St. Charles, Idaho. Here the insect has gone 100 miles along a main road, across mountain ranges, regardless of prevailing winds, and far from railroads.

That no one knows exactly how the weevils spread, may be inferred from the conflicting quarantine regulations designed by uninfested

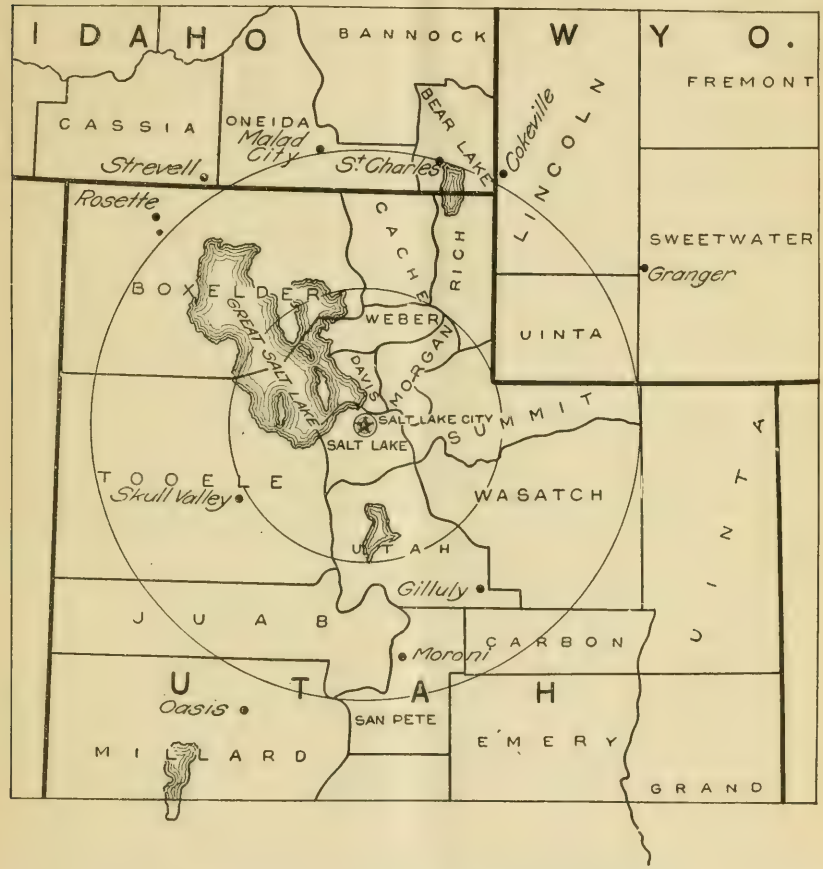

FIG. 3.—Map of portions of Utah, Wyoming, and Idaho, showing the district infested by the alfalfa weevil. The circles are 50 and 100 miles from Salt Lake City. (Original.)

States to exclude them. Thus, Arizona forbids the importation of nursery stock; California requires its fumigation at origin and delivery and forbids packing with hay, straw, or rushes; Idaho differs from California in permitting the use of rushes; Montana requires official fumigation at the point of origin; Oregon forbids the use of rushes and forage plants as packing; Arizona prohibits the importation of fruits; Montana, the importation of both fruits and vegetables from April 1 to October 31, except such as are inspected at designated points by the State of Utah from August 1 to October 31. Arizona and Oregon

prohibit the entrance of alfalfa seed; California and Idaho require it to be fumigated by an official after arrival; and Montana requires it to be so fumigated before shipment. Hay and straw of all kinds are barred by all five States. Bees in hives are refused admittance by California and Idaho; and Oregon requires that they shall not be packed in rushes, weeds, or forage. Household goods must be inspected before shipment into Arizona. Live stock can be shipped into Arizona only with the consent of the State entomologist and must be transferred to clean cars before crossing the line. California and Idaho prescribe that hay and straw must not be used in cattle cars, and Oregon forbids also grass and forage crops. Grain is barred from Arizona. Colorado, Wyoming, New Mexico, and Nevada have no restrictions on account of the alfalfa weevil.

In spite of the contradictory popular ideas of the means by which the alfalfa weevil travels, many facts which bear upon the question are definitely known. Live weevils do not occur in alfalfa seed, either before or after it is recleaned. They are seldom found in nursery packing of any kind, fruits and vegetables, or hay and straw used for packing, bedding, or feed, except under the following conditions: They are often found in green alfalfa fresh from the fields and in second-crop hay and potatoes which have been handled in contact with it; and they are found also in cured alfalfa hay, especially hay of the second cutting, in the stack, where some of them remain alive until the end of the following winter. They are found for several hours afterward in clothing which has been worn through infested fields in summer time, and sometimes remain even after the clothing has been packed in a trunk and shipped as baggage.

The occurrence of weevils in green alfalfa hay and new hay of the second crop is particularly important, because potatoes which are to be shipped are often hauled to the car upon a bedding of it to prevent bruising and are sometimes covered with it to protect them from the sun. This hay usually contains weevils, which crawl from the alfalfa to the sacks and are loaded into the tight refrigerator car, in which they often remain until it reaches its destination. Although no colonies have yet been started by this means, there is constant danger of it, which can be minimized by simply keeping the hay away from the potatoes.

Another important consideration as to the occurrence of weevils in new hay is that many people driving through the country in summer carry it for short distances as feed for their horses. The weevils may leave the hay as a result of the jar of travel, according to their habit; and that they do so is the more probable because no colonies have been found at any distance from the main territory, as would have happened if they were carried long distances by wagon. There is, however, a constant stream of traffic over certain main roads, composed of sheepmen, peddlers, and others bent on

business or social visits to other localities, near or remote. The carrying of weevils by these people, even if it be but for a mile or two, amounts in the aggregate to a systematic relaying of the species over through routes. There seems, in fact, to be a relation between the localities where alfalfa from infested fields is carried in this way and the country over which the weevils have spread most rapidly.

No connection can be traced between the railroads and the actual spread of the alfalfa weevil; in fact, the advance of the weevils has been rather less rapid along some railroads than in certain regions remote from them. The weevils occur rarely in baggage, express, and freight cars, and somewhat more often in passenger cars and refrigerator cars containing potatoes which have been handled with fresh second-crop alfalfa hay. Although there has been a large volume of unrestricted passenger traffic from the infested region during the past 12 years, no colonization of weevils has resulted; and although weevils have traveled in potato cars as far as Denver, Colo., Rock Springs, Wyo., and Butte, Mont., and many cars of potatoes which doubtless carried weevils were shipped throughout the Western States, no colonies have been started by this means.

The transportation of weevils on railroad trains and wagons is little affected by the flying of the species. It seemed reasonable at an early period of the investigation to believe that a beetle which flies abroad in the summer would alight upon various commodities and vehicles and be carried for great distances, but such is not the fact. Weevils are rarely found on trains or wagons except in cases where new hay is involved. The flight of the weevil not only plays a small part in its distribution by wagons and trains, but it is less general and extensive than it was once supposed to be. All records which are definite and authentic show only small numbers of the weevils in flight at any time. Reports dealing with immense numbers swarming in the air usually mention no specimens at all as actually caught, identified, and counted. They do not agree with the observations of this bureau, and many of them are probably based, by mistake, upon some other insect, such as the dung-beetle, Aphodius, which resembles the weevil in appearance and is always present in the air in larger numbers than the latter.

There is no evidence that the weevils ever fly for the purpose of seeking fields of alfalfa, either new or previously infested, or to find hibernation quarters. The most plausible theory is that their flight is caused by a rise in temperature, as are many activities of the lower animals. So far as can be learned, this flight is at random. It takes some of the weevils into new fields.

The crawling of the larvæ is unimportant as a method of spread, being limited to a journey of a few feet from one field to another, but the crawling of the adults is an important matter. During the cold weather of spring and fall a day's journey of an adult weevil is

only a few inches, but during the warm months the adults crawl during the greater part of the day or, in July and August, of the night. Although they use up much of their energy in climbing up and down plants, and into and out of crevices in the ground, so that it is largely wasted so far as progress is concerned, a little of it happens to lead to new fields. There is no general movement by crawling, any more than by flight, from the fields to the ditch banks, fence rows, and similar places, or from such places to the fields, at any time. The crawling is most important, as has been shown, in bringing weevils into hay and so into traffic, which probably takes them somewhat farther than they could go without help.

FIG. 4.—The alfalfa weevil: Work of the larvæ. (Original.)

During the 12 years that the alfalfa weevil has been in America it has spread into new territory very slowly and has agreeably disappointed those who feared that it would extend rapidly over all the alfalfa-producing regions of the continent. Its progress is so slow that there is hope of providing control methods for new climates and conditions as fast as these are encountered. There is hope also that the pest will not prove equally injurious under all circumstances. It is much less harmful in Europe than in America, owing apparently to climatic and industrial conditions, and it multiplies more slowly and does less damage in the higher altitudes in Utah and Wyoming than in the lower valleys. Nevertheless, it is possible that eventually every section of the country will have to consider, first, the problem of keeping the insect out of its boundaries, and later, the problem of growing alfalfa in spite of the weevil, or finding

a substitute for that valuable crop. It is therefore particularly desirable that farmers in the western mountains and plains should learn the appearance of the different stages of the weevil and be prepared to protect their crops.

DESCRIPTION OF THE WEEVIL IN ITS DIFFERENT STAGES.

THE FULL-GROWN LARVÆ.

The insect is most easily discovered, during the early years of its presence in new fields, in the form of the full-grown larva (fig. 2). It is then a green wormlike creature one-fourth of an inch long, with a black head and a faint white stripe down the middle of the back, and it feeds upon the leaves of the alfalfa mainly during late May, June, and early July. It can be found by sweeping the tops of the plants with an insect net, or by looking for the notches in the leaves where it has fed. When the larvæ are numerous they destroy most of the tender growth (fig. 4), causing the tops to appear white and making the field look at a distance as if frostbitten.

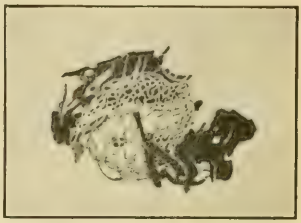

FIG. 5.—The alfalfa weevil: Cocoon attached to dead leaves. Much enlarged. (Original.)

THE NEWLY HATCHED LARVÆ.

The newly hatched larvæ are harder to find. They are only about one thirty-second of an inch long and remain hidden in the partly unfolded tips of the plants, where they are not easily seen or caught by the net. Their color is yellowish green, excepting the head, which is black. The color changes to green at the first molt, or shedding of the skin, and there is little change except in size during the two or three molts which follow, varying in number with the season of the year in which the larval life is spent.

THE PUPÆ AND COCOONS.

The pupal form is the one in which the change from the larva to the adult takes place. The pupa is contained within a delicate, oval, netlike cocoon (fig. 5), woven of a few white threads and attached, sometimes to the lower part of a green stem, sometimes to rubbish on the ground, and often to the inner side of a curled dead leaf. The pupa within this cocoon is somewhat like the larva in color, but more like the adult beetle in form, becoming still more like it in both respects as it approaches maturity.

THE ADULTS.

The adult is harder to find than the larva, but is present in the field throughout the whole year instead of the summer only. It is an oval brown beetle, three-sixteenths of an inch long, with a prominent snout projecting downward from the front of the head. The

color of old, weathered specimens is nearly black, owing to the dark ground color revealed by the shedding of the brown and yellow scales which at first clothe its upper surface. The adult stays close to the ground during early spring and late fall, but climbs about in the tops of the plants during the warm season. It is not readily seen by one walking through the fields, because it habitually drops to the ground when disturbed, and its color helps to make it invisible. It can be captured during the warm weather by sweeping the plants with a net and during the cooler spring and fall weather by sitting quietly in the field and catching it when it moves on the ground. In the winter it can be found by digging about the crowns and roots of alfalfa plants.

FIG. 6.—The alfalfa weevil: Eggs in split green stem. Enlarged. (Original.)

THE EGGS.

The eggs (fig. 6) are less conspicuous than the larvæ and adults, because they are usually concealed within the stems of the plants; but the holes in which they are placed are found in large numbers by examining the green stems during May and June, and in smaller numbers as early as March and as late as December. The eggs are small, oval, shiny globules, bright yellow when first laid, but dingy after a few days when incubation has begun, and adorned during the latter part of the incubation period with a black spot where the head of the little larva shows through the transparent shell. A few eggs, some of them infertile, are laid on the outside of the plants, and more in the weeds and grasses which grow in the field. Late in the fall and early in the spring there are many in the dead stems on the ground.

When an alfalfa grower outside the territory known to be infested finds in his field any insect which he suspects to be a form of the alfalfa weevil, he should send it to the Bureau of Entomology field station at Salt Lake City, Utah, to be identified. If it proves to be the alfalfa weevil, it is important that work should begin without delay, so that the measures that will be effective in controlling the pest under the new conditions may be learned. This work requires study of the traveling, feeding, mating, and egg-laying habits of the insect; of the effect upon it of climate, crop conditions, and farm operations; and of the agricultural conditions of the region, in order that the conditions favoring the growth, increase, and work of the weevil and the conditions necessary to destroy it or hinder its work may be ascertained. So far as these things are already known in regard to the country now occupied by the weevil they are here set forth.

HABITS OF THE WEEVIL.

WHERE AND HOW THE WEEVILS PASS THE WINTER.

When cold weather comes on the adult weevils creep down close to the ground and into crevices and spend the winter there. Some ditch banks and other uncultivated places which are strewn with the litter of dead vegetation harbor many of them, but these numbers are an insignificant part of those which remain in the fields and deposit eggs the following spring. Burning the grass and weeds in such places, therefore, while desirable in itself, gives practically no protection to the crop in neighboring fields.

Many weevils die in the fields during zero weather, but milder winter temperatures seem to have little effect upon them. Since bare ground freezes more than that which is covered by snow, it is sometimes advisable to cultivate the field in the fall, so that the snow which falls upon it may melt and expose the weevils as much as possible to the cold.

Owing to the fact that most of the weevils spend the winter on the ground in the fields, it is possible to kill them by flooding the field with muddy water and thus covering it with sediment.

There is no definite hibernation in this species. The adults are quiet when it is cold and active when it is warm. A female taken from the frozen fields will feed immediately and oviposit in a few hours after being brought into a warm room.

EARLY SPRING ACTIVITY OF THE WEEVILS.

The readiness with which the weevils resume their activities when subjected to warmth has an important bearing upon control measures. The weevils lay scattered eggs in early spring, many weeks before the regular laying season, and deposit numbers of eggs in the dry stems on the ground even before they begin climbing up the green plants and feeding upon them. Larvæ hatching from these eggs, with those from eggs laid under similar circumstances the previous fall, sometimes attack the plants in numbers large enough to cause serious injury to the crop before the majority of the eggs have been laid, particularly in years when there is an early spring. This early activity must be taken into account in any attempt to protect the first crop.

The fact that the adults feed rather freely for several weeks in early spring while the plants are small is the basis for attempts to destroy them by spraying with arsenical poisons. There is no danger of poisoning the live stock which may eat the hay, because the plants are too small at the time of spraying to hold much poison, and this early growth forms but a small portion of the hay crop. The amount of poison contained in hay from fields which have been sprayed only three weeks before cutting is too small to have any effect upon the most sensitive animals. The feeding of the adults is done chiefly after the usual time for the dormant spraying of orchards and before the early codling-moth spraying, and therefore

the work on the alfalfa fields need not conflict with either of those operations. Aside from its relation to spring spraying, this early feeding of the adults is chiefly important in that it gives the spores of Sackett's disease a chance to lodge within the tissues of the plant.[1] The damage caused by this blight is sometimes as serious as that done by the weevil larvæ themselves and is generally confused with it.

EGG LAYING OF THE WEEVILS IN LATER SPRING.

After feeding for several weeks, running about over the ground, depositing eggs in dry stems, and flying a little, the adults deposit large numbers of eggs in living stems. When the spring opens early they begin egg laying gradually, and the earliest eggs may hatch before the majority are laid. After a late spring the egg laying begins abruptly. In either case it is usually ended before June 10, and if the eggs can be destroyed up to that date, the attack of the larvæ will be prevented for the year. This can be done by pasturing the first crop so as to destroy the eggs after they are laid and before they hatch, or, at latest, while the larvæ are still small enough to cling to the leaves and be swallowed. This is the basis of the pasturing method and of a similar method of destroying the eggs and at the same time utilizing the first crop by cutting the alfalfa green and feeding it as a soiling crop.

WORK OF THE LARVÆ IN THE FIRST CROP OF ALFALFA.

If none of the treatments mentioned has been used, the larvæ appear in large numbers about the last week of May, or earlier if the spring has been favorable, and eat the leaves, especially on the young shoots, so rapidly that the plant is unable to outgrow the injury. At this stage, or a little earlier, it is necessary to cut the crop regardless of its condition, in order to prevent severe and perhaps total loss. The results of spring cultivation show at this time. The fields which have been cultivated grow earlier and produce a larger yield before cutting becomes necessary than do those which have been neglected. A few of the larvæ have finished feeding and spun their cocoons before even an early cutting. Most of the others spin during the month of June, though a few late larvæ are abroad in the field until winter.

When the first crop is removed, if the ground is dry and the weather clear and warm, many larvæ, pupæ, and adults die as a result of exposure to the heat of the ground. This mortality is increased if the ground is cultivated in such a way as to fill the cracks, crush the clods, and scrape off all remaining vegetation. This, in turn, is more easily accomplished if the soil has been kept in good condition by manuring and cultivation. The killing of the insects by heat is the foundation of the "brush-drag" treatment.

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[1] O'Gara, P. J. Bacterial blight of alfalfa in Salt Lake Valley. *In* Science, n. s., v. 39, no. 1016, pp. 905, 906. 1914.

SUMMER FLIGHT OF THE ADULTS.

The heat of the soil is also probably an important cause of that increase in the activity of the adults called the summer flight, which is greatest during the dry, hot weather beginning in June and ending in August. This flight accounts for the presence of many adults in grassy places and orchards, where they alight and find protection from the heat. It helps to restock fields in which the weevils have been killed and makes it necessary to repeat the treatment year after year, and on the borders of the infested district it contributes to the spread of the pest. The summer flight is not a general movement of the weevils from the fields to seek more suitable hibernation places elsewhere. There is no such movement, and virtually all of the weevils spend the winter in the fields.

WORK OF THE LARVÆ IN THE SECOND CROP.

If no treatment is given the infested field after haying, the larvæ which have been feeding upon the first crop gather upon the buds of the stubble, and although many have been killed by the heat of the earth after the cutting, there are still enough to prevent the sprouting of the second crop for a time nearly equal to its usual period of growth. By that time most of them have finished their feeding and growth and have gone into the pupal stage, and there is consequently no attack upon the later growth.

ACTIVITIES OF THE NEW GENERATION OF WEEVILS IN SUMMER AND FALL.

At the time of cutting the second crop the fields are full of weevils of the new generation, and there are usually many more weevils in the second-crop hay, which is cut at this time, than in that of the first and third crops. Their activity is greater at night than by day, and this condition continues until the cool nights of September begin. As autumn progresses, they haunt the plants less and less and fortunately are nearly all on the ground before the thrashing of the seed begins. No live weevils have ever been found in alfalfa seed.

About one-half of the females of the new generation of beetles are ready to deposit eggs by the middle of October, and egg laying, chiefly in dry stems, goes on for about a month after that time. Few of these eggs hatch before winter, and some of them hatch the following spring and probably take part in the early attack upon the first crop.

These habits of the weevil and the relations between it and the crop, the climate, and the country, comprise most of the facts for which a practical use has been found. Upon them are based all effective plans for preventing its ravages and retarding its spread.

RECOMMENDATIONS FOR THE CONTROL OF THE WEEVIL.[1]

SILTING.

Weevils can be killed in late winter or early spring by irrigating the fields with very muddy flood water and so burying them under

[1] In the field tests of spring and fall cultivation and the dust-mulch treatment the Bureau of Entomology has had the cooperation of the entomological department of the Utah experiment station.

a deposit of fine mud. This is practicable only where the irrigation system is without a settling reservoir, which is in itself an undesirable condition, but in the few cases where it can be applied the process is simple and inexpensive and the results good.

SPRING CULTIVATION.

Alfalfa fields in a weevil-infested region should be cultivated thoroughly in the spring with the spring-tooth harrow, disk harrow, or a similar tool, provided the crop is valuable enough to warrant the expense of the operation. Under conditions where cultivation is especially desirable, as where water is scarce or the soil does not naturally retain moisture well, this may increase the amount of the first crop as much as 50 per cent. It will cost from 60 cents to $1.25 per acre. In nearly every case it will be necessary to go over the field at least twice; and if the soil is in such condition that a double harrowing does not pulverize the soil and kill the weeds and grass, systematic manuring, cropping, and cultivation to improve the soil are desirable. Spring cultivation has no appreciable effect on the weevils, but merely hastens the growth of the alfalfa so as to give a larger yield when the attack of the larvæ in May or June makes early cutting necessary.

SPRING SPRAYING.

As soon as the weevils begin feeding upon the leaves of the plants, which usually happens early in April, the field may be sprayed with from 50 to 100 gallons per acre of a mixture of arsenite of zinc and water, in the proportion of 4 pounds of powder in 100 gallons. Owing to war conditions it may be impossible to obtain this poison at the present time. Arsenate of lead has not so far proved successful as an early spring spray.

On several occasions when it was intended to spray fields in early spring, circumstances prevented it, and the spray was applied about May 1, after many larvæ had hatched from the eggs and attacked the crop. In several of these cases the results were good, although the amount of foliage which must be covered is larger at this time than in early spring. Arsenate of lead, in the usual orchard strength of 4 pounds to 100 gallons of water, was as effective at this time as arsenite of zinc.

The attachment which is recommended for use with the hand-pump or gasoline-engine outfit for spraying alfalfa fields resembles the potato or beet sprayer. It is a horizontal pipe, 3 feet above the ground, fastened across the back of the truck of the power sprayer (fig. 7) or the wagon in which the hand pump is carried, and stiffened by lashing to a 2 by 4 scantling as long as the pipe itself. To provide for the attachment of the supply hose from the pump and the nozzles which distribute the liquid, the pipe is built up of 30-inch pieces of one-half inch galvanized iron pipe, coupled by T's, except

at the middle, where a cross is used, and the ends are fitted with L's. Unless reducing T's, L's, and cross can be obtained, a $\frac{1}{2}$ inch by $\frac{1}{4}$ inch bushing must be used for each nozzle, and in either case the attachment is made by means of a short one-fourth inch nipple. The hose lead from the pump is attached by means of a hose coupling. There should be a stopcock between the hose coupler and the main pipe to cut off the flow and maintain pressure whenever it is necessary to stop spraying in order to clean or repair nozzles.

The number of joints of pipe and nozzles to be used depends upon the capacity of the pump. A $2\frac{1}{2}$ horsepower engine and a good pump will supply seven nozzles of the eddy-chamber type, with $\frac{3}{64}$ inch holes in the disks, and maintain a pressure of 150 to 200

FIG. 7.—Alfalfa sprayer with power pump, in use against the alfalfa weevil. (Original.)

pounds. Some hand pumps will hardly supply three nozzles The nozzles are likely to become clogged, no matter how much care is taken to have the solution and the apparatus free from foreign particles. In addition to such precautions, therefore, it is wise to use nozzles provided with direct cleanouts at a slightly higher cost, as the time saved in operation makes up for the extra cost. Before work is begun, the tank, pump, hose, iron pipe, and nozzles should be thoroughly cleaned to remove particles of rust, sediment, and other foreign matter. The water and poison should be screened through fine brass strainer cloth. Attention to these details makes the difference between economical and expensive spraying, as clogging of the nozzles means costly delay for the entire outfit.

The cost of spraying with a power sprayer will depend largely upon the distance water must be hauled. It should range from 70

cents to $1.05 per acre when the usual price is paid for poison, the use of machine, the services of the operator, and the labor of the team and driver. Spraying does not take the place of spring cultivation in improving the condition of the soil and hastening the growth of the crop, nor does cultvation take the place of spraying in preventing the work of the weevils. The two operations are independent of each other, and in many cases both are desirable.

PASTURING.

If spraying is out of the question, the first and second crops may be protected by destroying the eggs after they have been laid in green stems, or the small larvæ after they have hatched and begun feeding in the tips, by pasturing the field. The success of this as a method of killing the insects depends upon managing the grazing in the right way and continuing it until most of the eggs have been laid; that is, until after the usual cutting time of the first crop. Instead of being pastured over the entire area at once, the field should be divided into two or three lots, with fencing suitable for the kind of live stock that is to be used, and the lots should be pastured alternately, so that each, after being eaten down close to the ground, will have a chance to grow up before the animals are turned in again. The number and size of the lots should be proportioned to the producing power of the field and the number of animals to be pastured, so that each lot may be grazed close to the ground about once in two weeks.

The pasturing may begin as early as the growth of the alfalfa will permit, and the change from each lot to the next should be made as soon as the larvæ which have developed in the next lot begin to feed upon the plants. On the other hand, the change should not be made until the lot which is being pastured has been grazed close. The number of animals which are necessary is regulated by these requirements, varying at different times with the rate of growth of the alfalfa. It may sometimes be advisable, when the stock has eaten most of the lot clean but allowed the plants to grow tall in certain spots, to mow these spots rather than to compel the animals to graze them.

The work may be considered finished as soon as most of the weevil eggs have been laid, which means a little later than the usual cutting time of the first crop. A good, practical method of deciding this question is to continue the pasturing until the lot containing the oldest growth continues free from signs of larval feeding past the time when the appearance of larvæ is to be expected, according to the experience of the season.

The area which can be protected from the weevils in this way is limited by the amount of live stock available. Three and one-half

acres of rather poor alfalfa handled in this way will support from forty to fifty 60-pound hogs, or a corresponding number of other animals.

According to the statements of agricultural experts, this way of preventing weevil injury deserves more notice than its usefulness for that purpose alone warrants, owing to the fact that, when combined with the proper feed of grain, alfalfa pasture furnishes an economical method of fattening live stock. Many farms would probably be more profitable if their management centered about the pasturing of stock on alfalfa, with the growing of enough other crops to provide grain and forage throughout the year. This is a matter that each must work out for himself to suit local conditions. Wherever the pasturing method is practicable it will solve the alfalfa-weevil problem.

SOILING.

Cutting the alfalfa green two or three times during the season and feeding it gives results similar to those of pasturing. It is especially suitable for dairy farms.

THE DUST MULCH.

If the weevils have not been killed earlier, they may be destroyed after removing the first crop by removing nearly all the vegetation, crushing the clods, and filling the cracks so as to expose the entire surface of the field to the sun. This is best done by such cultivation as will cover the field with a dust mulch, the dust being an additional means of killing the weevils which escape the heat of the ground. Success depends largely upon doing the work when the ground is dry and the weather warm and bright. It should not be attempted in cold, cloudy, or wet weather, nor soon after irrigation.

Dragging the field twice with a brush drag is sufficient if the soil is already mellow, but most fields need one or two cultivations with the disk or the spring-tooth harrow, and some grassy fields with heavy soil can not be put into the best condition to kill weevils until after they have been systematically improved for several years. A tool which is used instead of the brush drag in Salt Lake Valley is built by stretching several layers of heavy woven-wire fencing under an ordinary spike-tooth harrow with the teeth laid flat, and adding enough weight to pulverize the soil.

The dust-mulch method has practically no value as cultivation, since it must be followed by irrigation, which packs the surface dirt and restores it to the condition which obtained before cultivation. Its value depends entirely upon the fact that it kills the insects and so permits the second crop to grow. It is open to the objections that it requires time and the labor of men and horses during the busiest season of the year and that it stirs up the stones on rocky fields.

SUMMER SPRAYING.

Many farmers have sprayed the stubble after removing the first crop, with results about qual to those of the brush-drag treatment. The same apparatus can be used as for the spring spraying, but the usual method has been to distribute the spray through two leads of hose and two Bordeaux nozzles, each handled by a man who walks behind the outfit or rides upon it and covers the ground as evenly as possible and as far as he can reach with the spray rod. Both Paris green and arsenate of lead, in the usual orchard strengths of 1 pound and 6 pounds, respectively, per 100 gallons of water, have been successful.

This treatment is more rapid than the brush-drag method, but it requires special machinery. For orchard districts it is very promising.

PUDDLING.

Several farmers have protected the second crop by dragging the stubble, while it is still wet from irrigation, with the land leveler or the clod breaker. This process embeds the insects in mud, in which they perish, and effectually prevents them from attacking the sprouts. It is easier than the dust-mulch method, but it is harmful to the soil and is not recommended.

PREVENTION OF SPREAD.

Equally important with the problem of coping with the weevil in the fields is that of preventing its spread into new territory or, at least, since that may be impossible, of giving it as little help as possible. Aside from the consideration that the prosperity of each section depends largely upon that of other sections, the spread of the weevil from one district to others is a distinct detriment to the former as well as to the latter in that it increases the distance from which hay for feeding purposes must be shipped and consequently increases its cost.

All commodities which are to be shipped or hauled out of infested territory should be kept from contact with growing alfalfa, and they should at all times be kept away from new alfalfa hay, particularly that which has been cut during July and August.

SUMMARY OF RECOMMENDATIONS.

The first and second crops of alfalfa can be protected from the alfalfa weevil by spraying the young growth in early spring, by proper pasturing, or by cutting and feeding the crop before the eggs in it have hatched, and in a few cases by covering the field with silt in early spring. The growth of the alfalfa can be stimulated and a larger yield obtained by cultivating the field in the spring. The second crop can be protected by spraying the stubble or by the dust-mulch treatment.

Care should be taken to avoid spreading the weevil by shipping out of the infested district either new alfalfa hay or articles which have been in contact with it or with growing alfalfa.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1916

GRASSHOPPER CONTROL

In Relation to Cereal and Forage Crops

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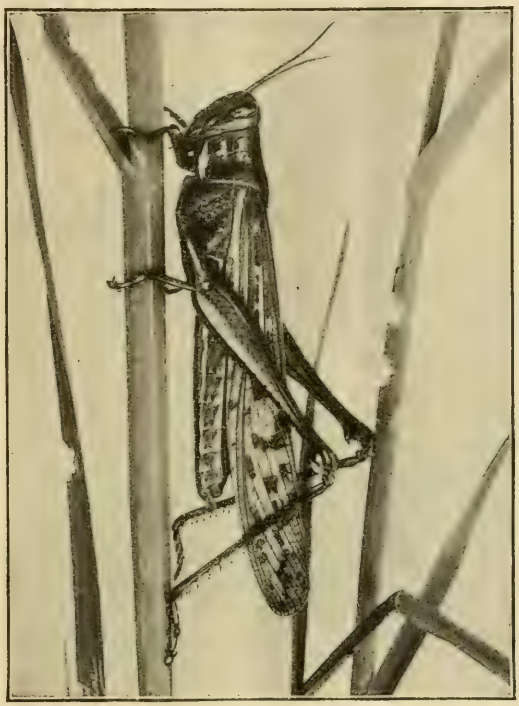
Insect Investigations



FARMERS' BULLETIN 747

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. October, 1916

ALTHOUGH grasshoppers are not usually noticed by the farmer until they have reached a considerable size, they begin to injure his crops immediately upon hatching from the egg. They should be detected and combated, therefore, while young and small, so that time, labor, and material, as well as crops, may be saved.

The destruction of grasshopper eggs by fall plowing, disking, or harrowing is recommended where practicable.

Hopperdozers or other grasshopper traps are sometimes partially effective where the lay of the fields and other infested areas will permit their use, but these appliances are seldom entirely satisfactory.

The best results can be obtained when all the farmers in a community cooperate.

The most practicable means of controlling grasshoppers is by the application of the poisoned baits described on pages 15 and 16 of this bulletin.

In the semiarid parts of the country, as in California and the Southwest, the poisoned baits should have water added to them to counteract the rapid drying and should be applied during the late afternoon.

Where the climate is moist, as in the Eastern and Southern States, the baits may be prepared without the water and applied during the early morning hours.

GRASSHOPPER CONTROL IN RELATION TO CEREAL AND FORAGE CROPS.

CONTENTS.

PRINCIPAL KINDS OF GRASSHOPPERS INVOLVED.

MANY kinds of grasshoppers are injurious to grains, grasses, and forage crops throughout the United States. The more important are the differential,[1] the two-striped,[2] the Carolina,[3] the lessor migratory,[4] the pellucid or clear-winged,[5] the red-legged,[6] the California devastating,[7] the southwestern lubber,[8] the Florida lubber,[9] and the New Mexico long-winged grasshopper.[10]

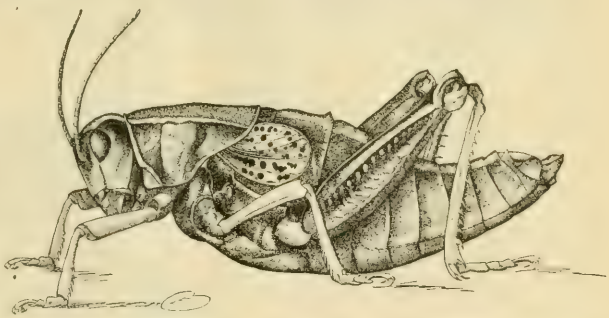


FIG. 1.—Southwestern lubber grasshopper (*Brachystola magna*): Adult female. Natural size. (Original.)

In the following pages is given a short description of these grasshoppers and the regions in which they occur, together with their life history, the crops attacked, and measures for controlling them.

The southwestern lubber grasshopper (fig. 1), a very large species, lives in the semiarid regions of the Southwest. It is usually pale green in color, speckled and marked with pink and brown, and is wingless throughout its entire life. It sometimes becomes injuriously abundant on the cattle ranges and dry farms of New Mexico and Arizona, but is found throughout the Great Plains region from

[1] *Melanoplus differentialis* Thom.
[2] *Melanoplus bivittatus* Say.
[3] *Dissosteira carolina* L.
[4] *Melanoplus atlanis* Riley.
[5] *Camnula pellucida* Scudd.
[6] *Melanoplus femur-rubrum* De G.
[7] *Melanoplus devastator* Scudd.
[8] *Brachystola magna* Gir.
[9] *Dictyophorus reticulatus* Thunb.
[10] *Dissosteira longipennis* Thom.

Wyoming and South Dakota to New Mexico and Texas. It is known to injure seriously corn, kafir, alfalfa, and grasses of various kinds.

The Florida lubber grasshopper (fig. 2) is a clumsy insect, often reaching the length of more than 2½ inches, and is correspondingly robust. It is usually yellowish in color, prettily marked with black, and its short and nearly useless wings are more or less distinctly stained with a bright crimson color. It inhabits the southern United States from North Carolina to Texas and has been especially injurious throughout the newly reclaimed regions in the State of Florida. It has been found to attack corn, grasses, sorghum, cowpeas, soy beans, and other crops.

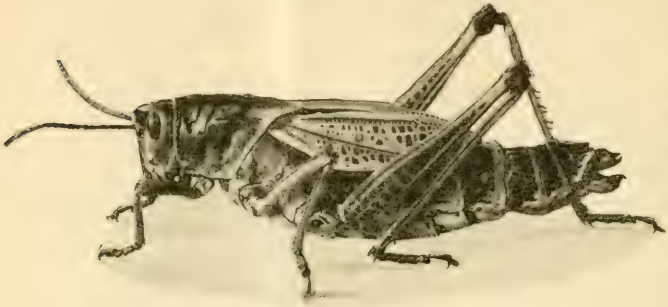


FIG. 2.—Florida lubber grasshopper (*Dictyophorus reticulatus*): Adult female. Natural size. (Webster.)

The differential grasshopper (fig. 3) is usually a yellowish-colored insect with clear glassy hind wings, averaging nearly 1½ inches in length. Its hind legs are usually distinctly marked with yellow and black, the colors arranged in chevron-shaped bars on the sides of the thighs. It is found throughout nearly the entire United States, although of rare occurrence in the Atlantic States. This grasshopper is chiefly injurious in the middle western and southwestern States, and is known to attack the following cereal and forage crops: Corn, sorghum, oats, wheat, bluegrass, soy beans, clover, and alfalfa.

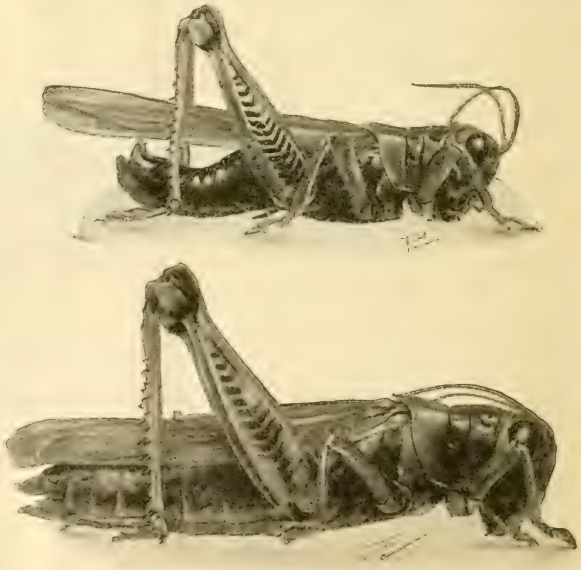


FIG. 3.—Differential grasshopper (*Melanoplus differentialis*): Above, adult male; below, adult female. Twice natural size. (Original.)

The two-striped grasshopper (fig. 4) is a compact, yellowish species, bearing, as its name implies, two yellow stripes running from the forehead down each side of the otherwise brown back. It varies from 1 to $1\frac{1}{2}$ inches in length and its hind wings are nearly colorless. This species is found from southern Canada to Mexico, excepting the South Atlantic States, and is very injurious to such important crops as wheat, corn, grasses, alfalfa, and clover.

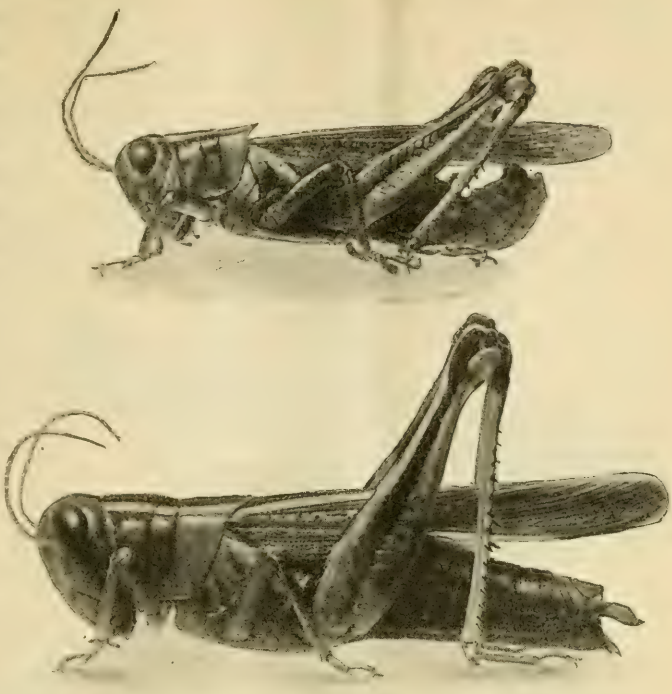


FIG. 4.—Two-striped grasshopper (*Melanoplus bivittatus*): Above, adult male; below, adult female. Twice natural size. (Original.)

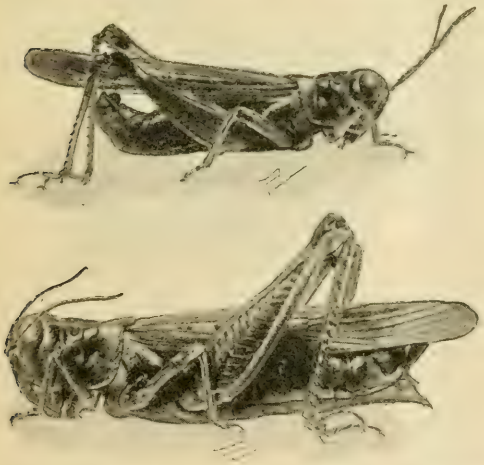


FIG. 5.—Lesser migratory grasshopper (*Melanoplus atlanis*): Above, adult male; below, adult female. About twice natural size. (Original).

The lesser migratory grasshopper (fig. 5) is a rather small, yellowish-gray species, averaging about 1 inch in length and bearing a distinct patch of black on the neck or collar. Although this grasshopper is comparatively small in size, it is a strong flier and sometimes does immense damage to alfalfa, grasses, timothy, corn, rye, soy beans, and wheat. It is found throughout nearly the entire United States, but is chiefly injurious in States west of the Mississippi River.

The red-legged grasshopper (fig. 6) is one of the most widely distributed of all the injurious species. It is a small, yellowish insect, having its legs partly tinged with a bright reddish hue. Its back is brownish and the hind wings are colorless. It is found in considerable numbers throughout the entire United States, southern Canada, and northern Mexico, and is known to injure seriously wheat, corn, bluegrass, oats, rye, timothy, and soy beans.

FIG. 6.—Red-legged grasshopper (*Melanoplus femur-rubrum*): Above, adult male; below, adult female. About twice natural size. (Original.)

The California devastating grasshopper (fig. 7) is a rather small species resembling somewhat the common red-legged grasshopper, but its injurious work is confined to the western United States, and especially California, where it frequently injures severely the alfalfa crop.

The Carolina grasshopper (fig. 8) is of moderate to rather large size, and is usually of a plain pepper-and-salt color, sometimes varying, in accordance with the soil upon which it is found, from gray through yellowish to a distinctly reddish color. Its hind wings are nearly black but are margined with yellow. Thus it is rendered inconspicuous while sitting upon the ground but catches the eye immediately upon taking flight. It is very widely distributed throughout the entire United States and is known to injure seriously corn, wheat, alfalfa, and soy beans.

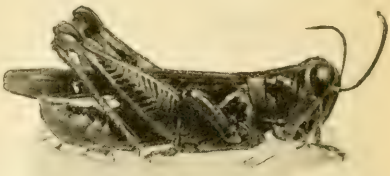


FIG. 7.—California devastating grasshopper (*Melanoplus devastator*): Adult male. About twice natural size. (Original.)

The pellucid or clear-winged grasshopper (fig. 9) is a small species having its hind, or true, wings clear or pellucid, while the front wings are distinctly blotched with brown. It is at times one of the most injurious species found within the limits of the United States. It has been especially injurious in the States of Idaho, Utah, and California, but is also found in Arizona and New Mexico. It is dis-

tributed throughout the northern United States from the Atlantic to the Pacific. This grasshopper is known to injure oats, wheat, grasses, and occasionally flax.

The New Mexico long-winged grasshopper (fig. 10) is a large, strong-flying species, often measuring more than 2 inches in length and is yellowish-gray, marked with chocolate-colored spots. It is known to exist in the central United States, from Idaho and Montana to New Mexico and Texas, and at times has been exceedingly injurious to the native grasses on the cattle ranges of New Mexico.

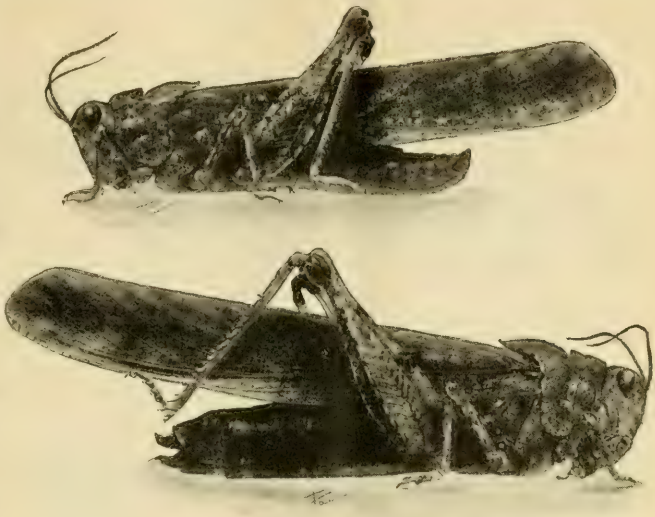


FIG. 8.—Carolina grasshopper (*Dissosteira carolina*): Above, adult male; below, adult female. About twice natural size. (Original.)

FIG. 9.—Pellucid or clear-winged grasshopper (*Camnula pellucida*): Adult female. About twice natural size. (Original.)

MANNER OF INJURY.

Grasshoppers, both young and old, injure crops in but one way, that is, by gnawing and devouring them wholesale, and where very numerous they have been known to consume almost every green thing in sight. Even the bark on the tender twigs of trees is eaten by these ravenous insects, which are known to gnaw the handles of agricultural tools, such as hoes and rakes, in order to secure the salt left upon them by the perspiring hands of the farmer.

CONDITIONS FAVORABLE TO OUTBREAKS OF GRASSHOPPERS.

It is generally believed in the middle and far western regions of the United States that when two dry summers occur in succession,

the second one usually produces serious outbreaks of grasshoppers. Whether or not this be true, there is ample evidence to show that dry weather favors the successful hatching of the eggs and the subsequent development of these pests. On the other hand, cool wet weather is unfavorable, and grasshoppers often die in great numbers from disease when such weather conditions prevail.

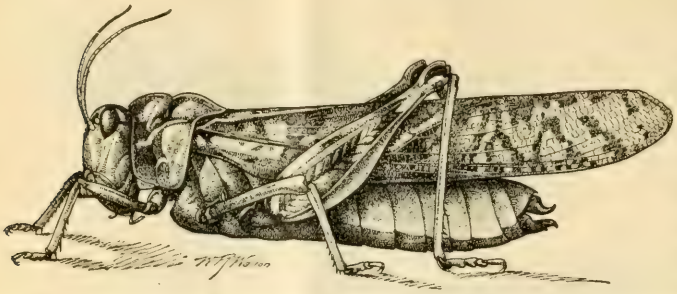


FIG. 10.—New Mexico long-winged grasshopper (*Dissosteira longipennis*): Adult female. About one-third enlarged. (H. E. Smith.)

LIFE HISTORIES AND DEVELOPMENT OF GRASSHOPPERS IN GENERAL.

The life histories of the various species of injurious grasshoppers are quite similar in character. The eggs are usually deposited in the soil, inclosed in sacs, or "pods" (fig. 11), formed of a glutinous substance furnished by the female. The grasshopper thrusts her tail or abdomen, which is capable of considerable extension, into the soil (fig. 12) and starts laying her eggs at the farther end of the tunnel thus formed, which is then filled with eggs and afterwards sealed. One grasshopper sometimes deposits a great many eggs. In the semiarid portions of the country, where the soil frequently becomes baked and hardened by the sun, the eggs are often laid in great numbers in the crowns of plants such as

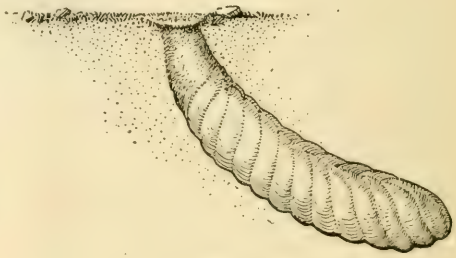


FIG. 11.—Sac, or "pod," of grasshopper eggs in the ground. Slightly enlarged. (Original.)

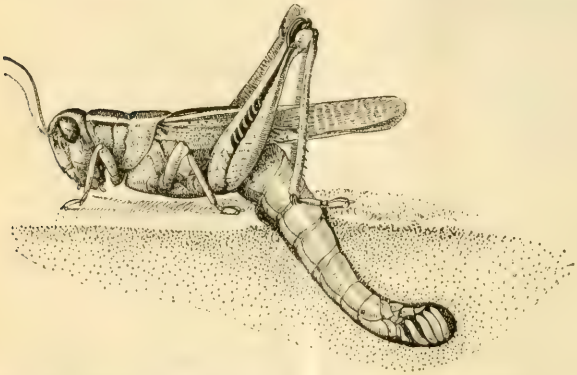


FIG. 12.—Two-striped grasshopper laying her eggs. (Webster.)

alfalfa, and in California as many as 2,000 eggs have been found in the crown of a single alfalfa plant.

The banks of irrigation canals are favorite egg-laying grounds for grasshoppers (fig. 13). In New Mexico and Arizona the eggs frequently are laid in the bottoms of shallow arroyos where they are inaccessible to cultivating implements. The waste lands of Idaho, Washington, and some other Northwestern States afford other instances where the destruction of grasshopper eggs is not practicable on a commercial scale.

The egg laying usually takes place in late summer or early fall and the young grasshoppers emerge the following spring. In some of the Southern and Southwestern States the young grasshoppers may emerge as early as February. In the North the eggs usually do not hatch until some time during the months of May or June.

In contrast with many other injurious insects, grasshoppers when hatched closely resemble their parents, excepting their lack of wings

FIG. 13.—An irrigation canal right of way where crowns of alfalfa plants contain thousands of grasshopper eggs to the square foot. (Webster.)

(fig. 14). There is no grublike larval stage nor is there any resting or true pupal stage such as is the case with butterflies and moths. The young grasshoppers are active and able to hop almost immediately upon emergence from the eggs. It takes from 70 to 90 days for the young grasshoppers to grow to maturity and develop wings. The farmer should therefore endeavor to attack the pest during its young stages, as this method not only requires less labor and material, but the insects can not then escape destruction by flying to untreated fields as they may, and often do, upon becoming mature. When the grasshopper reaches a certain stage of development its skin splits and is shed, the insect usually acquiring wings during the operation. It has then reached its final stage of growth and is ready to mate and reproduce its kind. So far as known the injurious species of grasshoppers have only one generation a year.

NATURAL ENEMIES OF GRASSHOPPERS.

INSECT ENEMIES.

Several kinds of parasitic two-winged flies deposit their eggs or maggots upon grasshoppers in their mature or nearly mature stage.

FIG. 14.—Young grasshoppers feeding on clover. Slightly enlarged. (Original.)

Among the most important of these is a blowfly or meat fly (fig. 15), which has been observed to deposit live maggots upon the wings of

the grasshoppers while they are in flight. The maggot of this parasite devours the internal portions of the grasshopper's body and soon causes its death. Robber flies (fig. 16) feed very largely upon young grasshoppers, grasping them in their long, stout legs, thrusting the strong beak through the body wall of the grasshopper and sucking out the liquid contents of the body. Several kinds of digger wasps (fig. 17) kill or stupefy grasshoppers by stinging, and then drag them into their underground nests, after which the wasp lays an egg upon the body of the grasshopper, which subsequently becomes food for the newly hatched grub. A number of blister beetles are known to prey in their younger stages upon the eggs of grasshoppers, but

FIG. 15.—A two-winged fly, *Sarcophaga kellyi*, parasitic on grasshoppers: Adult. About six times natural size. (Kelly.)

as the adult beetles are sometimes quite injurious to potatoes, beans, and other cultivated plants, they can not be considered as entirely desirable allies of the farmer.

WILD AND DOMESTIC BIRD ENEMIES.

The Bureau of Biological Survey has found that wild birds play a great part in the natural control of grasshoppers. These feathered friends of man are always present where grasshoppers abound and work almost constantly in aiding the farmer. The statement that all birds feed upon grasshoppers is so near the absolute truth that it needs only insignificant modifications. From the largest hawks to the tiny hummingbirds there are no exceptions other than the

strictly vegetarian doves and pigeons. Although birds of all families prey upon grasshoppers, the following may be selected as the most important destroyers of grasshoppers for their respective groups: Franklin's gull, bobwhite, prairie chicken, red-tailed, red-shouldered, broad-winged, and sparrow hawks, the screech and burrowing owls, yellow-billed cuckoo, road-runner, nighthawk, red-headed woodpecker, kingbird, horned lark, crow, magpie, red-winged and crow blackbirds, meadowlark, lark bunting, grasshopper and lark sparrows, butcher bird, wren, and robin.

FIG. 16.—A robber fly, *Promachus vertebratus*, which preys upon young grasshoppers: Adult. About three times natural size. (Original.)

Domestic fowls are also very fond of grasshoppers and feed greedily upon them whenever possible. Turkeys are sometimes killed by eating too freely of grasshoppers, the strong, rough hind legs of which cause severe lacerations or even puncturing of the crops of the birds.

HISTORICAL.

There exists ample evidence showing that grasshoppers, or locusts, as they are most often called in the Old World, have been reckoned among the principal insect enemies of agriculture since man began to till the soil. The writings of the Egyptians, Greeks, and ancient Hebrews all contain references to these insects as hateful pests of

the farmer. In North America unmistakable representations of grasshoppers are found on pottery and in the picture writings of the prehistoric Indians and Aztecs. It is therefore quite probable that grasshoppers attacked the maize and other crops of the Indians long before the coming of the white man. The early history of the New England States affords numerous records of the inroads by grasshoppers upon the crops of the settlers. During the period 1743 to 1756 a great scourge of these hungry insects occurred in Maine, and other outbreaks occurred in Vermont during the year 1797 to 1798. When agriculture began to be established generally in the Great Plains region of the United States, lying west of the Mississippi River and east of the Rocky Mountains, during the decade 1870–1880 a migratory species of grasshopper, commonly known as the Rocky Mountain locust,[1] frequently swooped down from its breeding grounds on the benches of the mountain range in such great swarms as to destroy practically all cultivated crops over vast areas of country. As the settlement of the Rocky Mountain region progressed and the breeding grounds of this destructive insect came under the influences of cultivation these outbreaks ceased. Thus, there has not been a serious general outbreak of the Rocky Mountain locust since 1880, and this particular grasshopper has ceased to be a pest of any great importance.

FIG. 17.—A digger wasp, *Prionopyx atratus*, which kills or stupefies grasshoppers by stinging them, and carries them into its nests as food for its young. Nearly three times natural size. (Original.)

However, there are many other kinds of grasshoppers having different habits which have since hampered the farmer and undoubtedly will continue to rob him of his crops for years to come unless persistent concerted action of agricultural communities in combating these pests succeeds in securing permanent relief.

[1] *Melanoplus spretus* Uhl.

CONTROL MEASURES.

There are three principal methods of control which have been found to be of greater or less practical value in combating grasshoppers in this country: First, the destruction of the eggs; second, catching the insects in the field by means of traps; and, third, the use of the poisoned baits.

DESTROYING THE EGGS OF GRASSHOPPERS.

It is seldom practicable to destroy the eggs because of the many different hiding places chosen by the grasshoppers in laying them and the impossibility of reaching the same with cultivating implements. However, where they are accessible the ground containing them should be thoroughly plowed, or disked, and harrowed in the fall, as these operations prevent the eggs from hatching successfully the following spring. Attempts to reach the eggs by handwork,

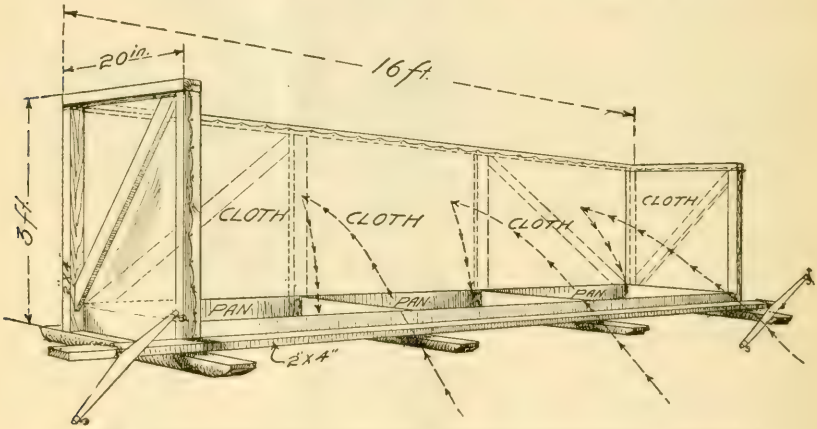


FIG. 18.—Hopperdozer with cloth back, showing construction. (Original.)

such as digging up the soil, is practicable only in gardens, truck farms, and places where intensive cultivation is practiced.

MECHANICAL MEANS OF DESTROYING GRASSHOPPERS.

The most common method of destroying grasshoppers mechanically is by the use of a simple horse-propelled implement or trap commonly called a hopperdozer. These implements are constructed along similar lines, but are of many slightly different patterns. As originally built the hopperdozer consisted of a galvanized sheet-iron pan or trough having a back rising at right angles to the pan. It was about 16 feet in length and mounted on runners made of wood or old wagon tires. Most of the hopperdozers recently constructed have a pan made of galvanized sheet iron, but the back and side wings are usually built with a wooden frame covered with stout muslin or light cotton duck, thus securing lightness and elasticity of structure. (Fig. 18.) The pan of the hopperdozer is kept partially filled with

water, upon which a film of low-grade kerosene, or coal oil, is maintained. When the implement has a cloth back and wings, these are kept moistened with kerosene oil. As the hopperdozer is drawn over the ground the grasshoppers jump or fly against its back and most of them are precipitated into the oil-covered water in the pan. A slight touch of oil is fatal to the insects. Thus, those that merely touch the oil-soaked back of the hopperdozer are usually killed, although they may not die immediately. The cheapest procurable grade of kerosene oil is perfectly satisfactory for use in a hopperdozer. An implement of this kind has been constructed recently with a back curving slightly forward. (Fig. 19.) The back and sides of this implement are covered with tin, nailed to furring strips carried by the uprights of the frame. It has been used successfully in western States, and it is claimed that the slight curve of the back and the slippery surface of the tin aid in precipitating the grass-

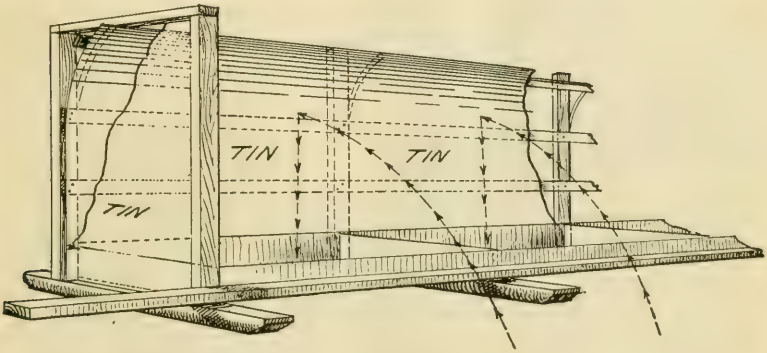


FIG. 19.—Showing construction of hopperdozer with tin back. (Original.)

hoppers into the pan. As many as 300 bushels of grasshoppers have been collected by the use of hopperdozers on 100 acres of alfalfa. But even where these implements may be used successfully, a great many grasshoppers escape being killed by them, and the fact that hopperdozers can not be used on uneven, stony, or recently cleared, stumpy ground, nor in meadows or fields of grain where the crops have reached a considerable height, makes it imperative that some more effective method of control be applied, and the poisoned baits have been found to supply this need satisfactorily.

POISONED BAITS AS A MEANS OF GRASSHOPPER CONTROL.

The mixture known as the poisoned-bran bait has been proven to be a simple, reliable, and cheap method of destroying grasshoppers, and has been applied with signal success throughout many portions of the United States. As prepared for ordinary use this bait is composed as follows: Wheat bran, 25 pounds; Paris green, 1

pound, or white arsenic, 1 pound; lemons or oranges, 6 finely chopped fruits; low-grade molasses, such as refuse from sugar factories, or cattle molasses, known as "black strap," 2 quarts. The bran and Paris green or other arsenical are thoroughly mixed while dry, the fruits are then finely chopped and added, and lastly the molasses is poured over the bait and the whole thoroughly kneaded. A coarse-flaked bran is most desirable, although where this can not be obtained easily ordinary middlings or alfalfa meal may be substituted; a low-grade, strong-smelling sirup or molasses, however, is essential to the entire success of the undertaking. Crushed ripe tomatoes, watermelons, or limes may be substituted for the lemons or oranges, if necessary. Ordinary powdered white arsenic (arsenious acid) contains nearly twice as much arsenic as Paris green and is comparatively low in price. The powdered form of arsenate of lead may be used, but in this case twice as much of it must be used

FIG. 20.—Sowing poisoned-bran bait from a buggy, in treating meadows to destroy grasshoppers. (Webster.)

as of the Paris green. In California and other semiarid regions water should be added to the bait at the rate of 4 gallons to 25 pounds of bran, as in these climates the bait dries out very rapidly and the extra moisture is necessary in order to attract the grasshoppers.

Another effective bait of similar character is the modified Criddle mixture. This is prepared as follows: Fresh horse droppings, one-half barrel; Paris green, 1 pound, or powdered white arsenic, 1 pound; finely chopped oranges or lemons, 6 to 8 fruits. This bait must be thoroughly mixed before being distributed and as most people object to handling this mixture with the bare hands, a pair of cheap rubber gloves may be used for the purpose. Both the poisoned-bran bait and the modified Criddle mixture are distributed over the infested fields by sowing broadcast, either on foot or from a light wagon or buggy, as shown in figure 20. A broadcast grain seeder

mounted on a wagon (fig. 21) has been used successfully for this purpose in the western portions of the country.

In applying the poisoned-bran bait in orchards, care must be taken to avoid distributing it close to the trees, because severe injury to fruit trees occasionally results from such applications of arsenical poisons.

Proper time for applying the poisoned baits.—The time of day chosen for distributing the poisoned baits has an important bearing upon the results secured. In California and other semiarid regions the bait should be distributed in late afternoon or early evening, just before the grasshoppers ascend the plants on which they usually pass the night. They are apparently hungry and thirsty at this time and greedily take the bait if it be available. In the moister portions of the country, such as New England and Florida, the bait is best applied early in the morning in order that the best results be secured. Farmers should not be discouraged if the grasshoppers do not drop dead immediately upon eating the poison, as it usually takes from one to five days for the full effect of the baits to become apparent.

FIG. 21.—Sowing poisoned-bran bait for grasshoppers by means of a broadcast grain seeder. (Webster.)

SUMMARY OF CONTROL MEASURES.

1. The most important and by far the most practicable means of controlling grasshoppers is by the application of the poisoned baits described on pages 15 and 16 of this bulletin. A strong effort should be made to apply these remedies when the grasshoppers are young, thus saving labor and material and therefore money. In the semiarid climates the baits should be applied during the late afternoon hours and should have water added to them as mentioned above. In moist climates, such as obtain in the Eastern and Southern States, the baits may be prepared without the additional water and applied during the early morning hours.

2. Where the topography of the infested fields will permit, the use of hopperdozers or other grasshopper traps is sometimes partially effective, but these methods are not often wholly satisfactory.

3. The destruction of eggs by fall plowing, or disking, and harrowing is recommended where practicable.

4. If the best results are to be obtained, the cooperation of communities is essential.

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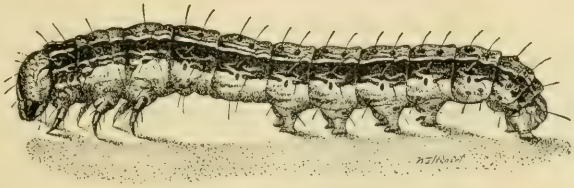
WASHINGTON : GOVERNMENT PRINTING OFFICE : 1916

THE FALL ARMY WORM, OR "GRASS WORM," AND ITS CONTROL

W. R. WALTON and PHILIP LUGINBILL

Entomological Assistants, Cereal and
Forage Insect Investigations



FARMERS' BULLETIN 752

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. November, 1916

IN PRACTICALLY all cases where the fall army worm commits serious injuries to cultivated crops the damage can be prevented if the farmer is on the alert to discover the insects when they first appear.

Every farmer should possess a practical spraying outfit. He should also keep on hand at all times a few pounds of one of the standard insecticides, such as arsenate of lead, Paris green, or arsenite of zinc.

The farmer should cultivate a spirit of suspicion with regard to this insect and realize that the finer the stand of young grain, the more tempting the bait for the army worm, and that a field of corn, beautiful, green, and rustling in the breeze, may at the same time have millions of young army worms devouring the crab grass between its rows, easily controlled if sprayed with arsenicals to-day, but which by to-morrow may have caused irreparable damage to his crops. In such cases a delay of twenty-four hours in securing advice or insecticides is usually fatal.

THE FALL ARMY WORM,[1] OR "GRASS WORM," AND ITS CONTROL.

CONTENTS.

INTRODUCTION.

This bulletin has been prepared with the intention of supplying the farmer and others with the necessary information for the control of the fall army worm (see illustration on title-page), together with a brief natural history of the species.

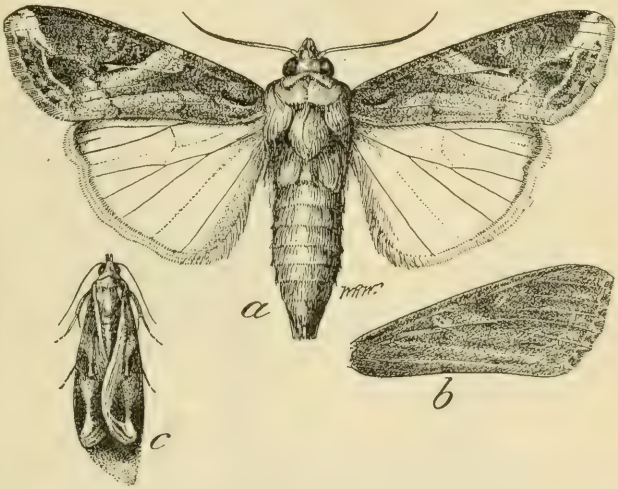


FIG. 1.—The fall army worm: *a*, Male moth; *b*, right front wing of female both; *c*, moth in resting position; *a*, *b*, about twice natural size; *c*, very slightly enlarged. (Original.)

This pest, which should not be confused with the true army worm,[2] is known, throughout the range of its injurious abundance, under many different names, some of which are the "grass worm," "overflow worm," "southern army worm," "Daggy's corn worm," "grass army worm," "alfalfa worm," etc. In Texas it is frequently called the "budworm." It is known in the North as the fall army worm because it occurs north of the Mason and Dixon line only in the late summer and fall. However, the injury inflicted by it under any of these names is usually disastrous to the farmer.

GENERAL DESCRIPTION.

The adult or parent of the fall army worm (fig. 1), a grayish moth, or "miller," is seldom noticed, and the farmer is far more likely to

[1] *Laphygma frugiperda* S. and A.; order Lepidoptera, family Noctuidae.

[2] The true army worm, *Cirphis unipuncta* Haw., is treated in Farmers' Bulletin 731.

see the full grown, nearly bare, striped caterpillars (fig. 1), his attention being called most forcibly to them by the widespread injury which they produce.

WHERE THE FALL ARMY WORM OCCURS.

During periodical outbreaks the fall army worm is found throughout almost the entire United States east of the Rocky Mountains, from Texas to Montana in the West and from Florida to Maine in the East. (Fig. 2.) It has also occurred recently in the Salt River Valley and at Yuma, in Arizona. Ordinarily it is apparently confined to the Gulf States, but under conditions favorable to its development this pest spreads northward as the summer advances, multi-

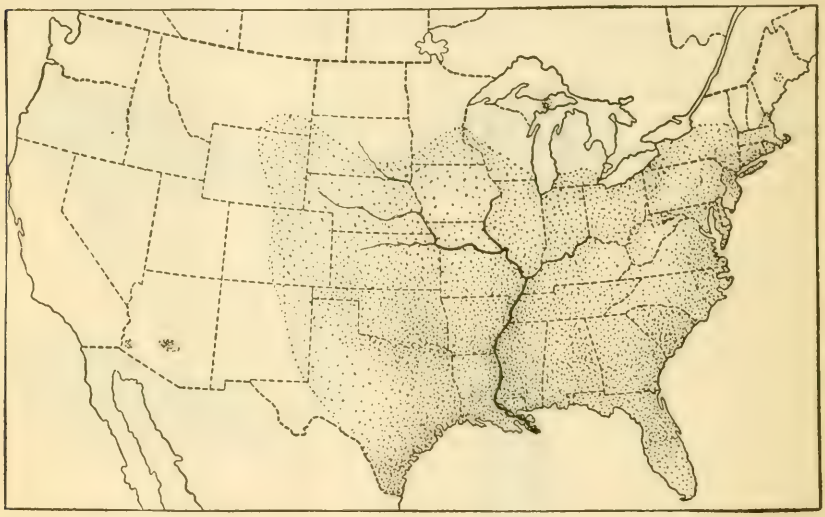


FIG. 2.—Map showing area sometimes invaded by the fall army worm. In the extreme southern portions of this area the fall army worm is always present. (Original.)

plying to such an enormous extent as to cause widespread and immense damage to cultivated crops throughout its range.

This pest is present every year in Central America, Mexico, and the West Indies Islands, and it seems quite possible that our worst outbreaks of the insect originate in these regions.

ECONOMIC IMPORTANCE AND MANNER OF INJURY.

The economic importance of this periodical invader, in the corn and cotton growing sections of the United States, can scarcely be exaggerated. The damage done by it in the Southern States during 1912 alone was enormous.

The caterpillars are exceedingly voracious in their nearly full-grown stage and devour stupendous quantities of food, eating almost continuously until they are ready to change to the adult form. They

usually feed more actively at night than during the daylight hours and more on cloudy days than on those during which the sun is shining brightly; but when they are numerous and food is not plentiful they may be seen many times taking or seeking food all day long, even in bright sunny weather.

CROPS ATTACKED.

The fall army worm attacks a great variety of crops, but its favorite food plants undoubtedly are the native grasses such as quack or crab grass, Bermuda grass, bluegrass, Johnson grass, etc. Where these plants are present in abundance it seldom attacks cultivated crops, and this serves to emphasize the necessity of clean cultivation, especially as regards corn, which is usually attacked only after the wild grasses, allowed to flourish between the rows, have been consumed. When the worms are observed feeding on such grasses these should be sprayed immediately with a solution of powdered arsenate of lead, 1 pound, or arsenite of zinc, 1 pound, to 50 gallons of water, in order to kill them before they attack the corn.

Besides corn, among cereal and forage crops, the fall army worm seriously injures kafir, rice, oats, millet, alfalfa, clover, sorghum, and cowpeas. The caterpillars are very fond of young sorghum. In the South, where it is a common practice to plant sorghum and cowpeas together for a hay crop, these worms frequently devour the sorghum plants from among the cowpeas—leaves, stem, and all, down to the very ground.

Cotton is severely injured at times, the caterpillars frequently cutting the tops of the plants completely off. Among other cultivated plants sometimes attacked are potato, sweet potato, turnip, spinach, tobacco, tomato, cabbage, cucumber, and grape. A full list of its occasional food plants would occupy so much space as to be out of place in this publication. In the cities of the North the fall army worm often devours the grass on lawns so rapidly as to cause consternation and astonishment to the owners.

WHERE INVASIONS OF THE FALL ARMY WORM ORIGINATE.

This insect is undoubtedly a native of tropical or subtropical America. It is apparently unable to survive the winter north of southern Georgia or central Texas, and, for this reason, is able to spread throughout the regions commonly visited by severe frosts only during the warmer portions of the year. During the years of its greatest abundance in the Southern States large numbers of the parent moths fly northward, by the aid of favorable winds sometimes making flights of hundreds of miles. After such flights the moths evidently lay their eggs at some chosen spot, the eggs hatch

and a fresh outbreak begins, and the female moths developing from the larvæ again fly northward before depositing their eggs. In this manner the fall army worm during favorable summers manages to spread over the entire eastern portion of the United States, even reaching southern Canada before the severe frosts of autumn intervene and halt its northward flight.

WHEN INVASIONS MAY BE EXPECTED.

General invasions of the fall army worm occur almost invariably following cold, wet springs. In some parts of the Mississippi Valley the pest is known as the "overflow worm," since the farmers attribute outbreaks of the insect directly to the overflowing of the great river, and it should be stated that there is evidence which appears to support this belief. The effects of cold and dampness on the insect enemies that ordinarily control the fall army worm are apparently disastrous, while such conditions have little or no ill effect on the caterpillars of the pest. It may be for this reason that local outbreaks occur nearly every year in the South in scattered localities after periods of heavy, localized rainfall and humid weather.

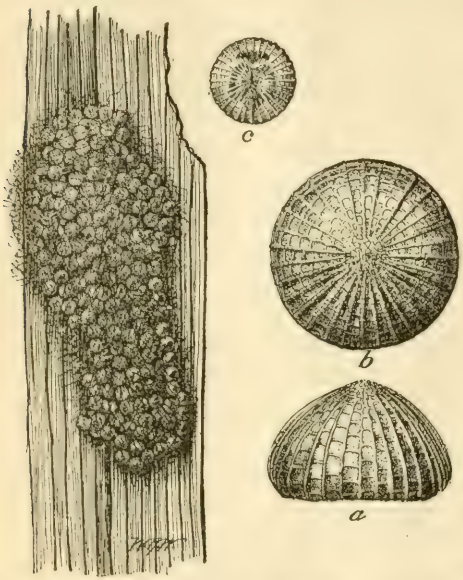


FIG. 3.—Eggs of the fall army worm: Egg mass at left about twice natural size; *a*, highly magnified egg, side view; *b*, same, view from above; *c*, greatly enlarged egg about ready to hatch, larva showing through the shell. (Original.)

LIFE HISTORY.

The fall army worm, in common with many other insects, passes through four stages in its development: First, the egg; then the larva, or caterpillar, which is the stage of growth and injury to crops; then the pupa, or resting stage; and, finally, the stage of the moth, or mature insect.

THE EGG STAGE.

The eggs (fig. 3) are laid by the moths at night in clusters of from 50 to several hundreds, preferably on grass blades. Low-lying fields thickly covered with grass or small grains are often chosen

for this purpose, and hence the outbreaks usually originate in bottom land. Sometimes, however, especially in cities, the eggs are laid among the grass blades on lawns. The color of the eggs is light gray and they are always more or less thickly covered with grayish down from the moth's body. The eggs hatch in from 2 to 4 days in the South, but sometimes require 10 days in the cooler climate of the Northern States.

THE CATERPILLAR, OR LARVAL, STAGE.

The newly hatched caterpillars (fig. 4) are very small and have jet-black heads and white bodies. They feed near the surface of the ground; thus, although myriads of them may be present, they are hidden from sight, and as they consume comparatively little food at this stage of their development the farmer does not often become aware of their presence. They feed first upon the shells of the eggs which have contained them, but soon begin to devour the crop. If the infestation is discovered at this time it usually can be brought quickly to an end by spraying with insecticides, or by mowing off the crop and then covering the infested spots with straw and burning them over.

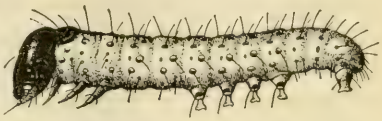


FIG. 4.—The fall army worm: Newly hatched larva, or "worm." Greatly enlarged. (Original.)

Within three or four days after hatching the young caterpillars have grown rapidly, turned much darker in color, and have begun to do considerable damage to the crop. At this time they do not entirely consume the leaves of the food plant, but skeletonize them, leaving the veins and ribs and whitish patches, which are conspicuous when seen against the green of the healthy portions of the leaf. The larvæ may be found in a curled position in the leaf sheaths, or possibly suspended by threads, but more than likely they will be found on the ground underneath the injured plant. The prompt application of arsenicals at this time is an easy matter, and is very effective in controlling the pest.

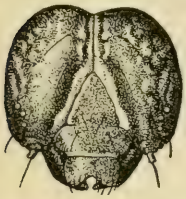


FIG. 5.—The fall army worm: Head of larva, front view. Greatly enlarged. (Original.)

From two to three weeks after hatching the caterpillar becomes fully grown. It is then striped, nearly naked, and about 1½ inches in length. (See title-page.) In this stage the fall army worm resembles the caterpillar of the true army worm so closely that it is practically impossible for the farmer to distinguish them. The caterpillar of the fall army worm usually has the front of the head marked with a more or less distinct inverted Y (fig. 5), but this character is not always sufficiently well marked to serve as a reliable means of iden-

tification, as this caterpillar varies in color from light greenish to almost black. In their last stages of growth the fall army worms consume quantities of food which are really vast in comparison with their size. By this time they are devouring every blade and leaf, leaving only the toughest parts of the plant stems uneaten. If the appetite of the worms is still unsatisfied when all of their local food supply has been eaten they mass together and crawl or "march" in search of other crops, and this affords the farmer an opportunity of killing the pest in great numbers by one of the mechanical methods described on pages 14 and 15.

When the caterpillar of the fall army worm becomes full grown it changes to the resting stage, or pupa. As a usual thing, practically an inch or two, and by twisting and turning presses the earth away from the body on all sides, thus forming a small cell, within which it changes to the resting stage or pupa. As a usual thing, practically all the worms enter the soil at about the same time, and their sudden disappearance frequently causes astonishment and mystification to the uninitiated observer. After the cell is completed the caterpillar begins to shrink in length, and presently the skin splits and is shed and the pupa appears already formed beneath it.

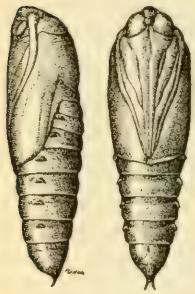


FIG. 6.—The fall army worm: Pupa. About twice natural size. (Original.)

THE PUPA, OR RESTING, STAGE.

The pupa (fig. 6) of the fall army worm is somewhat similar to a shelled peanut or date seed in shape and size, but is rounded at one end and pointed at the other. The color at first is golden or reddish, but finally becomes almost black. The skin or covering of its body is smooth and leathery, and it has no legs and is unable to move any portion of its body but the tail, or abdomen.

If the soil containing these pupæ can be lightly cultivated at this time, the insects are easily destroyed, for their underground cells are broken up and the pupæ are thus crushed or exposed to the action of the sun, rain, and their wild-bird and other enemies.

The resting, or pupal, stage lasts from ten days to two weeks; then the skin of the pupa is burst and the moth or parent crawls forth and makes its way immediately to the surface of the ground.

THE MOTH, OR PARENT, STAGE.

The moth of the fall army worm is somewhat smaller than that of the true army worm, measuring about ¾ inch in length and a little less than 1½ inches across its outspread wings, and these wings are

totally different in hue. The front wings (fig. 1) are dark gray in ground color and have a mottled appearance, and there is usually an irregular white or light-gray spot near their extreme tip. The front wings of the female (fig. 1, *b*) are usually much duller in color than those of the male. The hind wings of both sexes are white, but possess a pearly or pinkish luster; they are edged with a smoky brown line. The body of the moth is ash gray.

In the Gulf States there may be as many as six generations of moths in a given locality in one year, but five is probably the more usual number. In those regions where the winter temperatures descend much below the freezing point there is seldom or never more than one generation of the fall army worm in a given locality in any one year, as the moths resulting from an outbreak of the caterpillars almost invariably fly northward, sometimes for hundreds of miles, before laying their eggs. Thus, as the insects can not survive the winter in the North, this is the sole means of infestation for the Northern States, and if it were possible thoroughly to control the fall army worm in the Gulf States during the early spring, farmers in the North would probably never suffer from its ravages. As yet, however, no effective means of doing this has been discovered.

HISTORY OF THE FALL ARMY WORM IN THE UNITED STATES.

The fall army worm has been known as an injurious insect in Georgia since the year 1797 and perhaps earlier than this. It is recorded as having been particularly injurious in Florida in 1845, and it was at this time that the ditching method of destroying the "marching" worms, now in universal use, was first put into practice. In 1870 the insect was injurious in Missouri and Illinois and from then until 1899 more or less extensive damage by it occurred every few years. During the latter year an extensive outbreak of the pest occurred throughout South Carolina, North Carolina, Virginia, West Virginia, Indiana, Illinois, Missouri, Kansas and other western and northern States. The most severe general outbreak of this insect ever recorded occurred during the summer of 1912, when it swept almost the entire United States east of the Rocky Mountains, utterly destroying the corn and millet in parts of many southern States, severely injuring cotton and truck crops, and destroying the grass on lawns in cities as if by magic.

NATURAL ENEMIES.

INSECT ENEMIES.

Fortunately the fall army worm has several very efficient insect enemies which ordinarily succeed in keeping its numbers down, thus preventing serious outbreaks of the pest, except during years when exceptionally favorable conditions for the worm prevail.

In the southern portion of the country several wasplike enemies are always present, one of the most effective of these being a small,

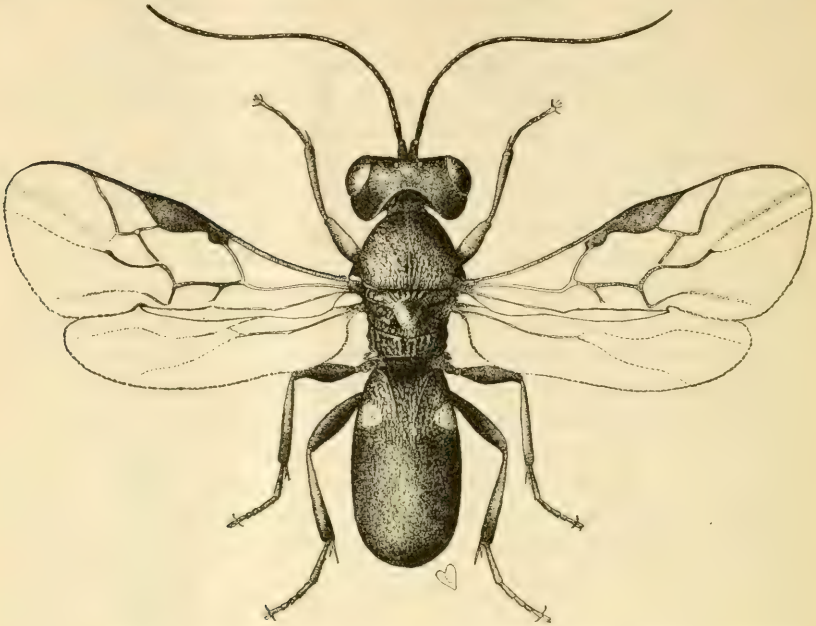


FIG. 7.—*Chelonus texanus*, a parasite of the fall army worm. Greatly enlarged. (Original.)

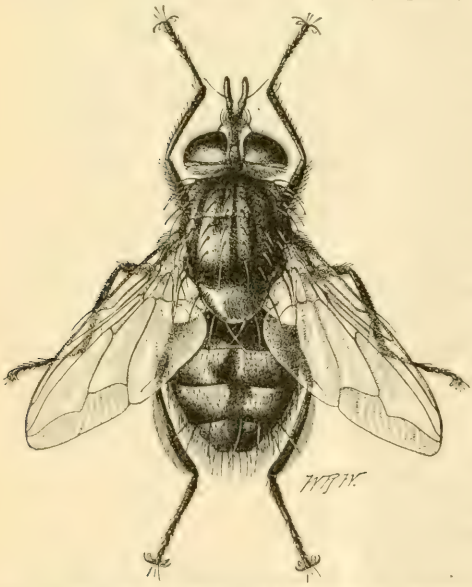


FIG. 8.—*Winthemia quadripustulata*, a fly parasitic on the fall army worm: Adult. Much enlarged. (Walton.)

black creature (fig. 7) which lays its eggs in the egg deposited by the fall army worm moth. Strange to say, instead of destroying this egg the young parasite remains inactive until the caterpillar has hatched and is partly grown, whereupon it devours the inside portions of the caterpillar's body, killing the pest.

Other valuable and effective insect enemies belong to a family of two-winged flies, not distantly related to that detested pest, the house fly. Some of these (see fig. 8) deposit their eggs on the bodies of the caterpillars, and the resultant maggots bore into the

caterpillar, soon killing it by devouring its internal organs and tissues. Another of these flies (fig. 9) lays exceedingly tiny eggs on the

FIG. 9.—*Archytas piliventris*, a fly parasitic on the fall army worm. Greatly enlarged. (Original.)

food plant of the fall army worm, which are swallowed by the unsuspecting caterpillar and hatch within its body, the maggots thereupon devouring the worm at their pleasure. Soldier bugs are numerous in some portions of the fall army worm's range. One of these, known as the spined soldier bug (fig. 10), kills and devours the caterpillars by piercing them with its strong beak and sucking out the liquid contents of their bodies. Both the old and young (fig. 11) bugs have this habit and are active enemies of the fall army worm.

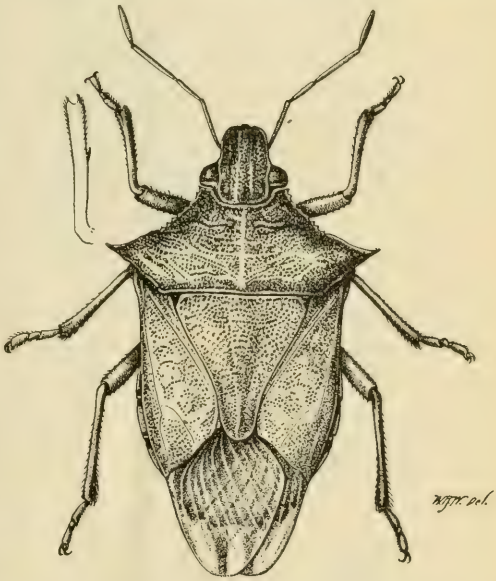


FIG. 10.—The spined soldier bug (*Podisus maculiventris*), an enemy of the fall army worm: Adult bug. Greatly enlarged. (Original.)

WILD-BIRD AND OTHER ENEMIES.

Among the important enemies of the fall army worm are our common wild birds. Some of these are the following: Crow blackbird or grackle, yellow-headed blackbird, chipping sparrow, bluebird, mocking bird, and meadowlark.

Domestic fowls will feed readily on the caterpillars if allowed access to infested fields, but will, of course, take only those individuals which they can reach from the ground.

Toads undoubtedly eat many caterpillars, while skunks feed upon the insects in both larval and pupal stages and are of far greater value to the farmer in this manner than is generally realized.

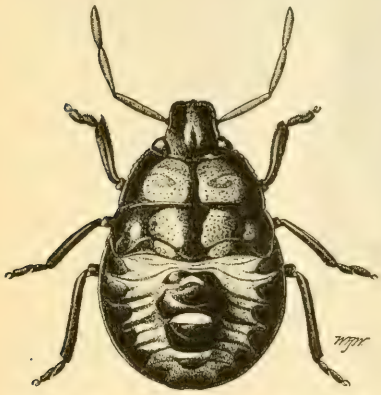


FIG. 11.—The spined soldier bug: Nymph, or young. Greatly enlarged. (Original.)

CONTROL MEASURES.

THE IMPORTANCE OF WATCHFULNESS AND PREPAREDNESS.

In practically all cases where the fall army worm commits serious injuries to cultivated crops the damage can be prevented if the farmer is on the alert to discover the insects when they first appear. Every farmer should possess a practical spraying outfit. Such outfits are not necessarily expensive, as they may be purchased at prices to suit almost any pocketbook. He should also keep on hand at all times a few pounds of one of the standard insecticides, such as arsenate of lead, Paris green, or arsenite of zinc. These are reliable and may be kept indefinitely without loss or deterioration in closed containers. A copy of Farmers' Bulletin No. 127 should be at hand, as this publication, which can be secured free of charge by application to the Secretary of Agriculture, tells how to mix and apply insecticides in controlling all classes of injurious insects. By observing these precautions and keeping a constant watch over his growing crops, the farmer should be in a position to meet invasions of fall army worms or other caterpillars and easily vanquish these pests before they have had a chance to commit serious damage to his crops.

The farmer should cultivate a spirit of suspicion with regard to this insect and realize that the finer the stand of young grain, the more tempting the bait for the army worms, and that a field of corn, beautiful, green, and rustling in the breeze, may at the same time have millions of young army worms devouring the crab grass between its rows, easily controlled if sprayed with arsenicals *to-day*, but which by to-morrow may have caused irreparable damage (fig.

12) to his crops. In such cases a delay of 24 hours in securing advice or insecticides is usually fatal.

SPRAYING FOR THE FALL ARMY WORM.

If the worms are found feeding in crab grass or other grasses or on grasslike grains other than corn, where the stand is not too thick

FIG. 12.—Corn plant, showing severe injury by the fall army worm. (Original.)

for the worms to be reached easily by the insecticide, they should be sprayed with a mixture of 1 pound of powdered arsenate of lead to 50 gallons of water, or, if the paste form of lead arsenate be used, 2 pounds to 50 gallons of water.

When feeding on corn the worms usually attack the bud of the plant first and are more difficult to reach because of the hairiness of the corn leaves. In this case a mixture of 2 pounds of powdered arsenate of lead or 3 to 4 pounds of the paste to 50 gallons of water is required, and the spray should be applied so as to force the fluid deep into the bud of the corn in order to reach the worms feeding

there. Paris green is sometimes used in place of arsenate of lead, but it should never be sprayed on corn unless lime has been added to it as follows: Paris green, 10 ounces; freshly slaked lime, 2 pounds; water, 50 gallons. If the poison is applied without the lime it will ruin the corn by burning.

White arsenic should never be applied to growing crops in any form, as it is strongly caustic and will burn them. Arsenite of zinc may be safely used as a spray in the proportion of 1 pound to 50 gallons of water if 1 pound of freshly slaked lime is added to the mixture. It may be applied in the same manner as the arsenate of lead spray.

THE POISONED-BRAN BAIT.

Under some conditions the poisoned-bran bait is of the greatest value in controlling the fall army worm. It is composed as follows: Wheat bran, 50 pounds; Paris green or white arsenic, 1 pound, or powdered arsenate of lead, 2 pounds) ; low-grade molasses, or "black-strap," 2 gallons. The bran and insecticide are first mixed together dry, the molasses is then added, and the whole mass is thoroughly combined. In locations where the mixture dries out quickly, salt at the rate of 5 pounds to 50 pounds of bran tends to keep the bait in a moist condition and renders it more effective. In some cases the addition of six finely chopped lemons or oranges to the mixture has been found to be advantageous. The bait is usually scattered broadcast over the infested fields and seems to be especially effective when the caterpillars are "marching," or in fields where their preferred foods, such as the wild grasses, are not present or have been partly consumed.

MECHANICAL MEANS OF CONTROL.

When the fall army worm has exhausted its food in a restricted locality and the worms have massed together and "marched" away seeking a fresh supply of provender, a narrow ditch with steeply sloping sides should be dug or plowed out directly across the path of the marching worms. In attempting to cross this ditch the worms will gather in great quantities therein and may be destroyed easily by crushing them with a log dragged back and forth through the ditch. (Fig. 13.) Shallow postholes dug at frequent intervals in the bottom of the furrow will trap many worms, which then may be destroyed by crushing or otherwise. Where the subsoil is but slightly permeable, the holes may be partially filled with water and a layer of coal oil, or petroleum, maintained upon its surface. The coal oil will soon kill the worms that fall into the fluid.

SUMMARY OF CONTROL MEASURES.

(1) Provide yourself with a spraying apparatus and keep on hand several pounds of some standard insecticide such as arsenate of lead, arsenite of zinc, or Paris green.

(2) Watch carefully the grass growing among the cultivated field crops in the bottom lands or in the low places of the fields and upon the first indication of the presence of these caterpillars apply poison spray as recommended in this bulletin.

FIG. 13.—Ditch prepared to entrap marching army worms. A log, dragged back and forth through the ditch, crushes the worms that have fallen into it. (Walton.)

(3) In case of a general invasion, after the caterpillars have gone down into the ground in order to change to the next stage, which is the pupa, give the ground a light cultivation, wherever this is possible. This will cause the death of many of the fall army worm pupæ.

(4) When the caterpillars are on the march, or are starting in on one corner of a field of grain, head them off by plowing a deep furrow directly in front of them. Then kill the larvæ falling into this furrow by dragging a log through it. Where the whole field is infested, plow a furrow around it so as to keep the worms out of the surrounding fields. Keep the furrows free from rubbish so that the larvæ will have no means of crossing to the farther side.

(5) Spray infested grass and other vegetation that has no value with a mixture of Paris green and water, 2 pounds of the former to 50 gallons of the latter. Do not use the sprayed grass or vegetation for forage.

Spray growing grasses and other forage crops intended for use at a considerably later date with one of the following mixtures:

(*a*)	Arsenate of lead (powder form)	1 pound.
	Water	50 gallons.
(*b*)	Arsenate of lead (paste form)	2 pounds.
	Water	50 gallons.

When corn is infested, apply one of the following poisonous mixtures:

(*a*)	Arsenate of lead (powder form)	2 pounds.
	(Or paste form, 4 pounds.)	
	Water	50 gallons.
(*b*)	Paris green	1 pound.
	Lime (freshly slaked)	2 pounds.
	Water	50 gallons.
(*c*)	Arsenite of zinc	1 pound
	Lime (freshly slaked)	1 pound.
	Water	50 gallons.

Never use white arsenic on plants; it will burn them.

(6) An immense amount of good can be accomplished in destroying these worms by the use of a poisoned bait which is scattered broadcast over the infested fields. Take 50 pounds of bran and mix with it either 1 pound of Paris green or 2 pounds of lead arsenate, then add 2 gallons of low-grade molasses and 6 finely chopped lemons. This is especially recommended for fields containing mixtures of grass and cowpeas, cowpeas and sorghum, or fields in which grass has been consumed by the caterpillars.

CAUTION: Do not pasture stock in fields where the grass or other crops have been sprayed with a poison mixture until after heavy rains have fallen and not before three weeks after the application of the insecticides.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 754 OCTOBER 14, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE BEDBUG.[1]

By C. L. MARLATT,

Entomologist and Assistant Chief of Bureau.

CONTENTS.

INTRODUCTION.

The presence of the bedbug (fig. 1) in a house is not necessarily an indication of neglect or carelessness; for, little as the idea may be relished, this insect may gain access in spite of the adoption of all reasonable precautions. It is very apt to get into the trunks and satchels of travelers, or into baskets of laundry, and may thus be introduced into homes. Unfortunately, also, it is quite capable of migrating from one house to another and will often continue to come from an adjoining house, sometimes for a period of several months, gaining entrance daily. Such migration is especially likely to take place if the human inhabitants of an infested house leave it. With the failure of their usual source of food, the migratory instinct of the bedbugs is developed, and, escaping through windows, they pass along walls, water pipes, or gutters, and thus gain entrance into adjoining houses. In these or other ways anyone's premises may be temporarily invaded.

[1] *Cimex lectularius* L.; order Hemiptera, suborder Heteroptera, family Cimicidae.

ORIGIN; COMMON NAMES; DISTRIBUTION.

As with nearly all the insects associated with man, the bedbug has had the habits now characteristic of it as far back as the records run. It was undoubtedly of common occurrence in the dwellings of the ancient peoples of Asia. The Romans were well acquainted with it, giving it the name Cimex. It was supposed by Pliny—and this was doubtless the common belief among the Romans—to have medicinal properties, and it was recommended, among other things, as a specific for the bites of serpents. It is said to have been first introduced into England in 1503, but the references to it are of such a nature as to make it very probable that it had been there long before. Two hundred and fifty years later it was reported to be very abundant in the seaport towns, but was scarcely known inland.

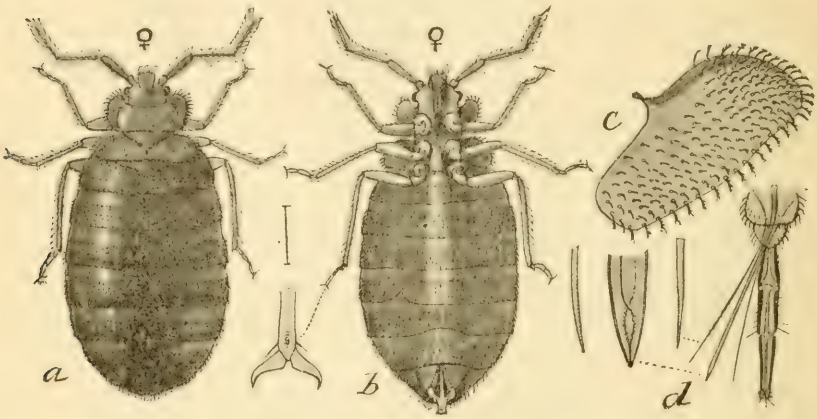

FIG. 1.—Bedbug (*Cimex lectularius*): *a*, Adult female, engorged with blood; *b*, same from below; *c*, rudimentary wing pad; *d*, mouth parts. *a*, *b*, Much enlarged; *c*, *d*, highly magnified. (Author's illustration.)

One of the old English names was "wall-louse." It was afterward very well known as the "chinch," which continued to be the common appellation for it until within a century or two, and is still used in parts of this country. The origin of the name "bedbug" is not known, but it is such a descriptive one that it would seem to have been very naturally suggested. Almost everywhere there are local names for these parasites, as, for illustration, around Boston they are called "chintzes" and "chinches," and from Baltimore comes the name "mahogany flat," while in New York they are styled "red coats," and in the west "crimson ramblers."

The bedbug has accompanied man wherever he has gone. Ships are very apt to be infested with it and have been the chief means of its wide distribution. It probably came to this country with the earliest colonists; at least Kalm, writing in 1748–49, stated that it was plentiful in the English colonies and in Canada, though unknown among the Indians.

VARIETIES AND RELATED INSECTS.

What may eventually prove to be mere variations of the ordinary type of human bedbug have been described as distinct species in several instances. For example, the common bedbug of southern Asia is supposed to present some slight variations from the European type, chiefly in being somewhat more elongate. These slightly diverging forms of the bedbug in different parts of the world, which are not known to have any special bird or animal host other than human beings, may prove to be merely local races or varieties of the ordinary bedbug.

Birds, bats, and poultry are attacked in various parts of the world by a considerable number of parasitic bugs, closely related to the bedbug, which live on their hosts and in nests and about roosting places. One of these species, occurring abundantly in southwestern United States and Mexico,[1] probably originally a parasitic messmate on birds and bats, has come to be an unmitigated poultry pest, and from the close association in these regions between poultry and human beings, is often a serious house pest—more so even than the true bedbug. Others of the species infesting birds and bats may also on occasion become house pests. For example, the nests of the common barn or eaves swallow of this country often swarm with the barn-swallow bug,[2] and from such nests under the eaves of dwelling houses these bugs sometimes gain entrance to houses and beds and are the cause of much annoyance. Similarly a species,[3] normally a parasite of birds and bats in the Old World, and also in Brazil and the West Indies, not infrequently becomes a human parasite.

GENERAL CHARACTERISTICS.

The bedbug belongs to the order Hemiptera, which includes the true bugs or piercing insects, characterized by possessing a piercing and sucking beak. The bedbug is to man what the chinch bug is to grains or the squash bug to cucurbs. Like nearly all the insects parasitic on animals, however, it is degraded structurally, its parasitic nature and the slight necessity for extensive locomotion having resulted, after many ages doubtless, in the loss of wings and the assumption of a comparatively simple structure. Before feeding, the adult (fig. 2) is much flattened, oval, and in color is rust red, with the abdomen more or less tinged with black. When engorged the body becomes much bloated and elongated and brightly colored from the ingested blood. The wings are represented by the merest rudiments, barely recognizable pads, and the simple eyes or ocelli

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[1] (*Cimex*) *Haematosiphon inodora* Dugès.

[2] (*Cimex*) *Occiacus hirundinis* Jenyns.

[3] *Cimex hemipterus* Fab. (synonym, *rotundatus* Sign.).

of most other true bugs are lacking. The absence of wings is a most fortunate circumstance, since otherwise there would be no safety from it even for the most careful of housekeepers. Some slight variation in length of wing pads has been observed, but none with wings showing any considerable development has ever been found.

THE "BUGGY" ODOR.

The most characteristic feature of the bedbug is the very distinct and disagreeable odor which it exhales, an odor well known to all who have been familiar with it as the "buggy" odor. This odor is by no means limited to the bedbug, but is characteristic of most plant bugs also. The common chinch bug affecting small grains and the squash bugs all possess this odor, and it is quite as pungent with these plant-feeding forms as with the human parasite. The possession of this odor, disagreeable as it is, is very fortunate after all, as it is of considerable assistance in detecting the presence of these vermin. The odor comes from glands, situated in various parts of the body, which secrete a clear, oily, volatile liquid. With the plant-feeding forms this odor is certainly a means of protection against insectivorous birds, rendering these insects obnoxious or distasteful to their feathered enemies. With the bedbug, on the other hand, it is probably an illustration of a very common phenomenon among animals, i. e., the persistence of a characteristic which is no longer of any especial value to the possessor. The natural enemies of true bugs, against which this odor serves as a means of protection, in the conditions under which the bedbug lives, are kept away from it; and the roach, which sometimes feeds on bedbugs, is evidently not deterred by the odor, while the common house ant and the house centipede, which may also attack the bedbug, seem not to find this odor disagreeable.

FIG. 2.—Bedbug: Adult before engorgement. Much enlarged. (Author's illustration.)

HABITS AND LIFE HISTORY.

The bedbug is normally nocturnal in habits and displays a certain degree of wariness, caution, and intelligence in its efforts at concealment during the day. Under the stress of hunger, however, it will emerge from its place of concealment in a well-lighted room at night, so that under such circumstances keeping the gas or electric light burning is not a complete protection. It has been known under similar conditions to attack human beings voraciously in broad

daylight. It usually leaves its victim as soon as it has become engorged with blood and retires to its normal place of concealment, either in cracks in the bedstead, especially if the latter be one of the wooden variety, or behind wainscoting, or under loose wall paper, and in these and similar places it manifests its gregarious habit by collecting in masses. It thrives particularly in filthy apartments and in old houses which are full of cracks and crevices, in which it can conceal itself beyond easy reach. As just noted the old-fashioned, heavy, wooden-slatted bedsteads afford especially favorable situations for the concealment and multiplication of this insect, and the general use in later years of iron and brass bedsteads has very greatly facilitated its eradication. Such beds, however, do not insure safety, as the insects are able to find places of concealment even about such beds, or get to them readily from their other hiding places.

Extraordinary stories are current of the remarkable intelligence of this insect in circumventing various efforts to prevent its gaining access to beds. Most of these are undoubtedly exaggerations, but the inherited experience of many centuries of companionship with man, during which the bedbug has always found its host an active enemy, has resulted in a knowledge of the habits of the human animal and a facility of concealment, particularly as evidenced by its abandoning beds and often going to distant quarters for protection and hiding during daylight, which indicate considerable apparent intelligence.

Like its allies, the bedbug undergoes what is known as an incomplete metamorphosis. In other words, the insect from its larval to its adult stage is active and similar in form, structure, and habit, contrasting with flies and moths in their very diverse life stages of larva, chrysalis, or pupa, and winged adult.

The eggs (fig. 3, *d*) are white oval objects having a little projecting rim around one edge and may be found in batches of from 6 to 50 in cracks and crevices where the parent bugs go for concealment. In confinement eggs may be deposited almost daily over a period of two months or more and commonly at the rate of from one to five eggs per day, but sometimes much larger batches are laid. As many as 190 eggs have been thus obtained from a single captured female.[1]

The eggs hatch in a week or 10 days in the hot weather of midsummer, but cold may lengthen or even double this egg period or check development altogether. The young escape by pushing up the lid-like top with its projecting rim. When first emerged (fig. 3, *a*, *b*) they are yellowish white and nearly transparent, the brown color of the more mature insect increasing with the later molts (fig. 4).

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[1] Girault, A. A. Preliminary studies on the biology of the bedbug, *Cimex lectularius*, Linn. III. Facts obtained concerning the habits of the adult. *In* Jour. Econ. Biol., v. 9, no. 1, p. 25-45. 1914.

During the course of its development the bedbug molts or sheds its skin normally five times, and with the last molt the minute wing pads, characteristic of the adult insect, make their appearance. A period of about 11 weeks was formerly supposed to be necessary for the complete maturity of the insect, but breeding experiments with

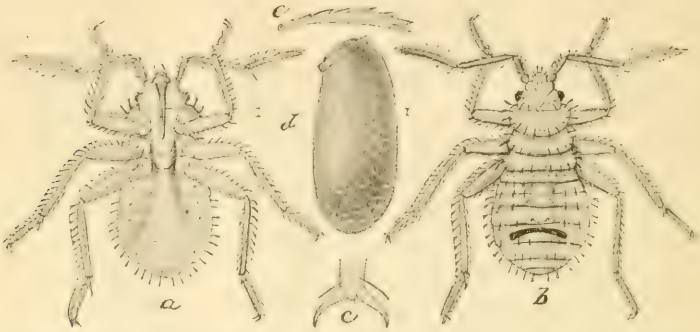

FIG. 3.—Bedbug: Egg and newly hatched larva: *a*, Larva from below; *b*, larva from above; *c*, claw; *d*, egg; *e*, hair or spine of larva. Greatly enlarged, natural size of larva and egg indicated by hair lines. (Author's illustration.)

this insect, conducted in this department in 1896, indicated that the life cycle is subject to great variation, being entirely dependent on warmth and food supply. Under favorable conditions of temperature and food it was found that there was an average period of about eight days between moltings and between the laying of eggs and their hatching, giving about seven weeks as the period under these

FIG. 4.—Bedbug: *a*, Larval skin shed at first molt; *b*, second larval stage immediately after emerging from *a*; *c*, same after first meal, distended with blood. Greatly enlarged. (Author's illustration.)

conditions from egg to adult insect. The molting periods are shorter in the earlier stages and lengthen in the later stages. There are many exceptions, however, and some individuals even under the same conditions remain two or three weeks without molting. Under conditions of famine, or without food, as already shown, the bedbug may remain unchanged in any of the immature stages for an indefinite

time, and the checking of development by such starvation may result in additional molting periods.

The breeding records referred to, and numerous confirmatory experiments subsequently made by other investigators, indicate that ordinarily but one meal is taken between molts, so that each bedbug must puncture its host five times before becoming mature, and at least once afterwards before it can develop eggs. Additional meals between molts may be taken under favoring circumstances, however, and particularly when the insect has been disturbed and has not become fully engorged at its first meal after a molting or other period. The bedbug takes from 5 to 10 minutes to become bloated with blood, and then retires to its place of concealment for 6 to 10 days for the quiet digestion of its enormous meal, and for subsequent molting, or reproduction if in the adult stage.

Such feeding and reproduction may, under favorable conditions of temperature, continue throughout the year, and in one instance the progeny of a captured female adult was carried through three continuous generations.[1]

Unfavorable conditions of temperature and food will necessarily result in great variation in the number of generations annually and in the rate of multiplication, but allowing for reasonable checks on development, there may be at least four successive broods in a year in houses kept well heated in winter.

FOOD AND LONGEVITY.

Under normal conditions the food of the common bedbug is obtained from human beings only, and no other unforced feeding habit has been reported. It is easily possible, however, to force the bedbug to feed on mice, rats, birds, etc., and probably it may do so occasionally in nature in the absence of its normal host. The abundance of this insect in houses which have long been untenanted may occasionally be accounted for by such other sources of food, but probably normally such infestation can be explained by the natural longevity of the insect and its ability to survive for practically a year, and perhaps more, without food.

There are many records indicating the ability of the bedbug to survive for long periods without food, and specimens have been kept for a year in a sealed vial with absolutely no means of sustenance whatever. In the course of the department's study of this insect in 1896, young bedbugs, obtained from eggs, were kept in small sealed vials for several months, remaining active in spite of the fact that they had never taken any nourishment whatever. A considerable

[1] Girault, A. A. Preliminary studies on the biology of the bedbug, *Cimex lectularius*, Linn. II. Facts obtained concerning the duration of its different stages. *In* Jour. Econ. Biol., v. 7, no. 4, p 163–188. 1912.

series of experiments was later conducted by Girault,[1] bearing on the longevity of the insect under different conditions. A large number of adults of both sexes were kept in confinement, but with normal feeding and mating, and these survived for periods ranging from 54 to 316 days. Similarly, the life of 71 newly hatched larvæ, without food, ranged from 17 to 42 days, averaging about 28 days. Partly grown captured insects lived without further feeding from 17 to 60 days. Longevity is naturally affected more or less by temperatures. In other words, temperatures sufficient to check the activity of the insect and produce hibernation or semihibernation are apt to increase longevity.

The fact that the bedbug is able to survive for such long periods without human blood has led to the theory that it could subsist in some fashion on the moisture from wood or from accumulations of dust in crevices in flooring, etc. There seems to be no basis of observed fact for this idea.

Another very prevalent belief among the old settlers in the West, that this insect normally lives on dead or diseased cottonwood logs, and is almost certain to abound in log houses of this wood, seems to be equally devoid of basis. As illustrating this belief, the department has on file a very definite report from an Army officer that the bedbug often occurs in numbers under the bark of dead cottonwood trees,[2] especially along the Big Horn and Little Horn Rivers in Montana. The basis of this report and the origin of this very general misconception is probably, as pointed out by the late Prof. Riley, due to a confusion of the bedbug with the immature stages of an entirely distinct insect,[3] which somewhat resembles the bedbug and often occurs under cottonwood bark.

INFLUENCE OF TEMPERATURE.

As a messmate of human beings in dwelling houses, the bedbug is normally protected from extreme cold, and is known to be an abundant and serious pest far north. In fact, it is often more troublesome in north temperate latitudes than farther south. This may be accounted for partly by the fact that the bedbug is very sensitive to high temperatures, and a temperature of 96° to 100° F. or more, accompanied with a fairly high degree of humidity, results in the death of large numbers of the bugs. The mature or partly mature bedbugs can stand comparatively low temperatures, even below freezing, for a considerable period. The eggs and newly hatched larvæ, however, succumb to a temperature below freezing, if this condition is prolonged for from 15 days to a month. The feeding and developing activity of the insect practically ceases at 60° F., the insect remaining quiescent and in semihibernation at

[1] Loc. cit. [2] *Populus monilifera.* [3] *Aradus* sp.

temperatures below this point. The most favorable temperatures for activity are between 60° and 98° F.[1] The activity of the insect is controlled entirely by temperature and food supply, and, therefore, in heated houses the insect may remain active throughout the winter. There is some protection in winter, therefore, in sleeping in cold bedrooms.

THE BITE OF THE BEDBUG.

The bite of the bedbug is decidedly poisonous to some individuals, resulting in a slight swelling and disagreeable inflammation. To such persons the presence of bedbugs is sufficient to cause the greatest uneasiness, if not to put sleep and rest entirely out of the question. With others, however, who are less sensitive, the presence of the bugs may not be recognized at all, and, except for the occasional staining of the linen by a crushed individual, their presence might be entirely overlooked. The inflammation experienced by sensitive persons seems to result chiefly from the puncture of the skin by the sharp piercing setæ which constitute the puncturing element of the mouth parts, as there seems to be no secretion of poison other than the natural fluids of the mouth.

The biting organ of the bedbug is similar to that of other insects of its order. It consists of a rather heavy, fleshy under lip (the only part ordinarily seen in examining the insect), within which lie four threadlike hard filaments or setæ which glide over one another with an alternating motion and pierce the flesh. The blood is drawn up through the beak, which is closely applied to the point of puncture, and the alternating motion of the setæ in the flesh causes the blood to flow more freely. The details of the structure of the beak are shown in figure 1 at *d*.

To allay the irritation set up by the bite of the bedbug, peroxide of hydrogen, or dioxygen, may be used with good results.

Tincture of iodine either at ordinary or double strength is also a good counter-irritant for use in cases of flea, mosquito, bedbug, and other insect bites, but should be used with caution on the tender skin of small children and on those who are affected with or disposed to eczemic disorders.

THE BEDBUG AND HUMAN DISEASES.

In common with other insects which attack man and warm-blooded animals, it is entirely possible for the bedbug and its close allies to be transmitters of contagious human diseases, and already these insects have been shown to be possible carriers or transmitters of a considerable series of diseases, including infantile Kala-azar of northern Africa and southern Europe, relapsing fever of Africa and Europe, the Chagas fever of Brazil, tropical sore, plague, and possibly

[1] Bacot, A. W. The influence of temperature, submersion, and burial on the survival of eggs and larvæ of *Cimex lectularius*. *In* Bul. Ent. Res., v. 5, pt. 2, p. 111–117. 1914.

leprosy. In the case of these, and perhaps other diseases, the bedbug shares the responsibility of transmitter with other biting insects, such as body lice and fleas.

The particular rôle of the bedbug as a carrier of disease has not been satisfactorily determined, nor has it been shown that the bedbug is a necessary alternate host in any instance. In general, the transmission of disease by this insect has apparently resulted from the accidental carriage of the disease elements on the mouth parts, as pointed out by André,[1] after a careful study of the subject. As a parasite of human beings in private dwelling houses, where it may seldom change its host, the opportunity for the bedbug itself to become infected with human diseases and again to transmit them to the human subject is very remote. This condition, however, does not apply to hotels or to passenger boats, where the human occupants are constantly changing. Furthermore, the fact that the bedbug attacks its host at comparatively long intervals of from a week to several weeks or months acts as a bar to its transmission of certain insect-borne diseases, the biology of which requires a definite and comparatively short period of development in the alternate insect host.

NATURAL ENEMIES OF THE BEDBUG.

Living always in houses as it does and being well concealed, the bedbug is not normally subject to much if any control by natural enemies. Certain other household insects, however, do occasionally prey upon the bedbug, as, for example, the house centipede [2] and the common little red house ant.[3] Such enemies, however, are of very small importance and yield little, if any, effective control except under very exceptional circumstances. One such instance is reported by the late Mr. Theodore Pergande, of this department, who states that as a soldier in the Civil War he occupied at one time a barracks at Meridian, Miss., which had been abandoned some time before. The premises proved to be swarming with bedbugs; but very shortly afterwards the little red house ant discovered the presence of the bedbugs and came in enormous numbers, and Mr. Pergande witnessed the very interesting and pleasing sight of the bedbugs being dismembered and carried away bodily by these very minute ants, many times smaller than the bugs which they were handling so successfully. The result was that in a single day the bedbug nuisance was completely abated. The liking of red ants for bedbugs is confirmed also by a correspondent writing from Florida (F. C. M. Boggess), who goes so far as heartily to recommend the artificial introduction of the ants

[1] André, Ch. Recherches anatomiques et expérimentales sur la punaise des lits. *In* Jour. Physiol. et Path. Gén., v. 14, p. 600-615. 1912.

[2] *Scutigera forceps* Raf.

[3] *Monomorium pharaonis* L.

to abate this bug nuisance.[1] Bedbugs and other household insects, however, are not of the sort which it is convenient or profitable to turn over to their natural enemies in the hope that eradication by this means will follow, and the fact that they are preyed upon by other insects furnishes no excuse to the housekeeper for not instituting prompt remedial measures.

REMEDIES.

Undoubtedly the most efficient remedy for the bedbug is to fumigate the infested house or rooms with hydrocyanic-acid gas. This gas will penetrate into every crevice in the house or room where the bedbugs conceal themselves and has an immediate effectiveness which gives it an important recommendation, especially when the infestation is considerable or of long standing. This method of fumigation should be intelligently employed, as the gas is deadly poisonous. A bulletin giving directions for such fumigation has been issued by the Department of Agriculture.[2]

The fumes of burning sulphur are also a very efficient means of control where the conditions are such that this method can be used, readily destroying the insect in all stages, including the egg. The treatment is inexpensive compared with the use of hydrocyanic-acid gas and offers much less risk of danger to human beings. There is, however, a considerable risk of injury to household fabrics, furnishings, and wall papers from the strong bleaching quality of sulphur fumes. This danger will be somewhat diminished if the fumigation can be done at a time when the room or house is thoroughly dried out, as in winter by a furnace or other heating system. Further precautions should be taken by removing all metallic surfaces from the room or building, or by protecting them with a coating of vaseline. Two pounds of sulphur are recommended for each 2,000 cubic feet of space, and the building should be closed for the treatment for at least 5 or 6 hours, or preferably for 24 hours. Sulphur candles may be used where available, or the sulphurous gas or fumes can be generated by burning the sulphur in a dish placed in the center of the room, and for protection set within a larger vessel. Thorough-going precautions must be taken to prevent accidental overflowing or the starting of a fire, and after the fumigation the house should be given a thorough airing.

Other gases have been experimented with, such as formalin and the vapors of benzine, naphthaline, and camphor, but these gases are of little value. Similarly, insect powders are of little value, largely from the difficulty of getting them into the crevices and other places of concealment of the insects.

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[1] Bedbugs and red ants. *In* Insect Life, v. 6, no. 4, p. 340. 1894.

[2] Howard, L. O., and Popenoe, C. H. Hydrocyanic-acid gas against household insects. U. S. Dept. Agr. Farmers' Bul. 699. 8 p. 1916.

The old-fashioned household remedies referred to below are effective enough, though at a greater cost of time and personal effort. They will, however, be often of much service in the case of slight or recent infestations, or where the employment of more poisonous and troublesome gases is objected to or is impracticable. Of these simple methods of control perhaps the most efficient is in very liberal applications of benzine or kerosene, or any other of the lighter petroleum oils, introduced with small brushes or feathers, or by injecting with syringes into all crevices of beds, furniture, or walls where the insects may have concealed themselves. Corrosive sublimate is also of value, and oil of turpentine may be used in the same way. The liberal use of hot water, wherever it may be employed without danger to furniture, etc., is also an effectual method of destroying both eggs and active bugs.[1]

Various bedbug remedies and mixtures are for sale, most of them containing one or another of the ingredients mentioned, and these are frequently of value. The great desideratum, however, in a case of this kind, is a daily inspection of beds and bedding, particularly the seams and tufting of mattresses, and of all crevices and locations about the premises where these vermin may have gone for concealment. A vigorous campaign should, in the course of a week or so at the outside, result in the extermination of this very obnoxious and embarrassing pest.

The possibility of temperature control is indicated in the discussion elsewhere of the effect of temperature on this insect, and it may be that if infested houses in cold climates could be opened up and allowed to remain at a temperature well below freezing for a week or more, the bedbug would be thoroughly exterminated. This method of control would be rarely practicable except perhaps in the case of summer houses which are left untenanted in winter.

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[1] A remedy for the bedbug has been devised by Mr. R. H. Pettit ("Notes on two insecticidal agents," *in* 10th Rpt. Mich. Acad. Sci., p. 159–160, 1908) as a substitute for hydrocyanic-acid gas and sulphur, and is reported to have proved very successful. The preparation of this insecticide and its application is described as follows:

Alcohol is drawn through pyrethrum in a funnel until the powder is well washed and a large part of the resinous principle extracted. To do this, the powder is placed in a large funnel with filter-plate and a layer of cotton wool at the bottom. An aspirator is attached and the alcohol is at first slowly and later rapidly sucked through six or eight times, during which operation it becomes highly colored. To this liquid as a basis, are added several oils to give permanence to the application. Both alcohol and pyrethrum evaporate so quickly that it was thought best to carry in some heavier volatile oils whose effects would last several days or even weeks. The formula when completed stands as follows:

To the extract made by washing 400 grams of pyrethrum with 2,000 c. c. of strong alcohol, are added—

50 grams gum camphor.
150 c. c. cedar wood oil.
25 grams oil citronella.
25 grams oil lavender.

The application is best made with a large sized atomizer, one holding a pint or more and working with a piston instead of a rubber bulb. * * * To obtain the best results, repeat the treatment after about two weeks. We have tried this mixture repeatedly, and with uniformly gratifying results. Usually one application, if thoroughly made, put a period to the complaints, about eight or ten ounces being required in an average sleeping-room. The odor remains some little time in a room, but is not disagreeable to the average person.

This remedy can be readily prepared by a pharmacist in any drug store.

UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 762 OCTOBER 21, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE FALSE CHINCH BUG[1] AND MEASURES FOR CONTROLLING IT.

By F. B. MILLIKEN, *Scientific Assistant, Truck Crop and Stored Product Insect Investigations.*

INTRODUCTORY.

The grower or gardener of the plateau region east of the Rocky Mountains is often alarmed to note that his sugar beets or cabbages, which a day or two previously had been apparently free from insects, are swarming with minute, active, grayish bugs which, by their numbers, threaten the profitable harvesting of his crop. These insects belong to the species commonly known as the false chinch bug.

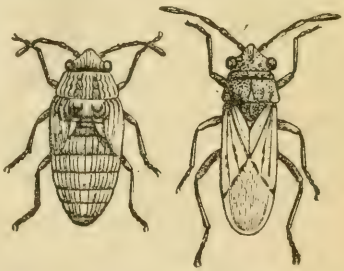

FIG. 1.—The false chinch bug (*Nysius cricae*): Adult at right, last stage of nymph at left. Highly magnified. (Adapted from Riley.)

A severe outbreak of this pest, especially in Kansas and Colorado, during May and June, 1916, makes it desirable to inform market gardeners and sugar-beet growers of the best means that have been developed for combating it in that region. The ability to recognize the insect when it appears and a knowledge of its life history and habits are essential to the successful application of remedial measures.

The adult false chinch bug (fig. 1) is about one-eighth of an inch long and one-twentieth of an inch wide, or about half the length and half the width of a grain of wheat. To one familiar with the true chinch bug it is sufficient to say that the false chinch bug resembles it, including the offensive odor, but is more slender, and there is no

[1] *Nysius cricae* Schill. (*N. angustatus* Uhl.); family Lygaeidae, order Hemiptera, suborder Heteroptera.

black on the wing covers. Others will recognize the insect from the description given above and its dull gray body, which is black beneath and half covered by its whitish wings. The young are wingless and may be recognized from their occurrence with the adults.

GENERATIONS AND FOOD HABITS.

The number of generations, or "broods," produced annually depends upon the temperature, the latitude, and the season. At Garden City, Kans., there are at least five. The early spring and the late fall broods deposit their eggs in the surface cracks of the soil and in pulverized soil. During the hottest weather they thrust their eggs among the clustered parts of plants, such as the heads of the great-flowered gaillardia,[1] the flowering parts of carpet-weed,[2] and the glumes of "stink-grass" or strong-scented love-grass.[3]

When the young are hatched they feed almost exclusively on weeds, especially on pepper-grass,[4] shepherds-purse,[5] thyme-leaved spurge,[6] Russian thistle,[7] and sage-brush.[8] *Monolepis nuttalliana* (R. & S.), which has no common name, is also included in the list of food plants. At maturity the adult bugs scatter over all vegetation. If drought prevails they are compelled to gather on cultivated crops, preferring crucifers or cole crops and beets, but they have been observed feeding on corn and kafir. Seed beets during the second year's growth suffer especially.

While feeding, the false chinch bugs congregate in large numbers on a few plants. Here they remain until the sap is exhausted and the plants wilt, after which they collect on such other plants as are growing close by. When disturbed, the adults dart quickly to the ground or to adjoining plants. Those alighting on the ground crawl to plants when the disturbance ceases.

CONTROL MEASURES.

DESTRUCTION ON WILD PLANTS.

The false chinch bug may frequently be controlled by destroying it on its wild food plants, and since the effect on such plants need not be considered, this may be accomplished satisfactorily by burning, which is particularly effective when there is enough dead and dry vegetation on the ground to carry fire. This will compass the destruction of many of the adults as well as great numbers of the young. Burning may be facilitated by scattering straw or similar dry material over the infested area, and when the insects are massed on weeds or clumps of wild vegetation they can be destroyed by the use of a strong-blast gasoline torch. The best type of torch, costing

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[1] *Gaillardia pulchella* Foug.
[2] *Mollugo verticillata* L.
[3] *Eragrostis major* Host.
[4] *Lepidium virginicum* L.
[5] *Bursa bursa-pastoris* L.
[6] *Chamaesyce serpyllifolia* Pers.
[7] *Salsola tragus* L.
[8] *Artemisia tridentata* Nutt.

about $18, should be employed for this purpose. The ordinary plumber's torches are not satisfactory for field work, as they are almost certain to become overheated so that the operator can not use them, and in a short time the heat destroys their usefulness. The value of hand torches for insecticidal purposes is extremely limited, and growers are apt to expect too much from their use. They are applicable to only a few forms of insects, of which the present species is one.

DESTRUCTION BY CONTACT POISONS.

Adults which attack cabbages or sugar beets are readily killed by a spray of about 1 pound of fish-oil soap or strong laundry soap to 5 gallons of water. On turnips and radishes such a solution is too strong, and a solution of 1 pound of soap in 10 gallons of water with 1 part of nicotine sulphate in 1,000 parts of water should be used. Other crops whose resistance to strong soap solutions is not known should be treated with the latter solution. Those insects that survive the first treatment soon collect on other plants, where they may be destroyed by another spraying.

To spray an infested plant successfully it must be approached without disturbing the bugs and the nozzle held high enough above it to allow the cone of spray to surround the plant. The spray should then be turned on and the nozzle gradually lowered in order to wet the bugs on the ground, after which it should be directed among the leaves to wet those which are sheltered. It is best to attach the nozzle to the end of a 4-foot rod and to set it at right angles to the rod by means of an elbow.

CAPTURING THE BUGS ON STICKY SHIELDS.

A sticky shield for capturing the false chinch bug on plants that can not be sprayed has been developed by Mr. H. O. Marsh, of the Bureau of Entomology, and Mr. W. W. Tracy, jr., Bureau of Plant Industry, working at Rocky Ford, Colo. This shield consists of burlap, or gunny, stretched over a back of thin boards and protected by poultry netting which is tacked to end pieces 1 by 4 inches. Crude petroleum is spread on the burlap and sprinkled with kerosene to soften it. The shield is then held alongside the infested plant and the bugs driven onto it by striking the other side of the plant with a beater made of a piece of canvas tacked to a flat handle. The netting prevents the plant from brushing the oil off of the shield, but does not interfere with the bugs darting against it and sticking in the oil, or at least becoming sufficiently smeared to insure their death. The diagram (fig. 2) illustrates the construction of a shield and beater.

A convenient size of shield is 24 by 30 inches, and of the beater, 14 by 14 inches. Such a shield can be operated by one man, but better results can be secured by two. The petroleum and kerosene must be renewed frequently.

To combat this pest successfully and to prevent losses to his crops the grower should apply remedies at the very beginning of an attack. If the outbreak covers a large area, all growers in the locality should cooperate, as crops may be attacked anywhere in the neighborhood.

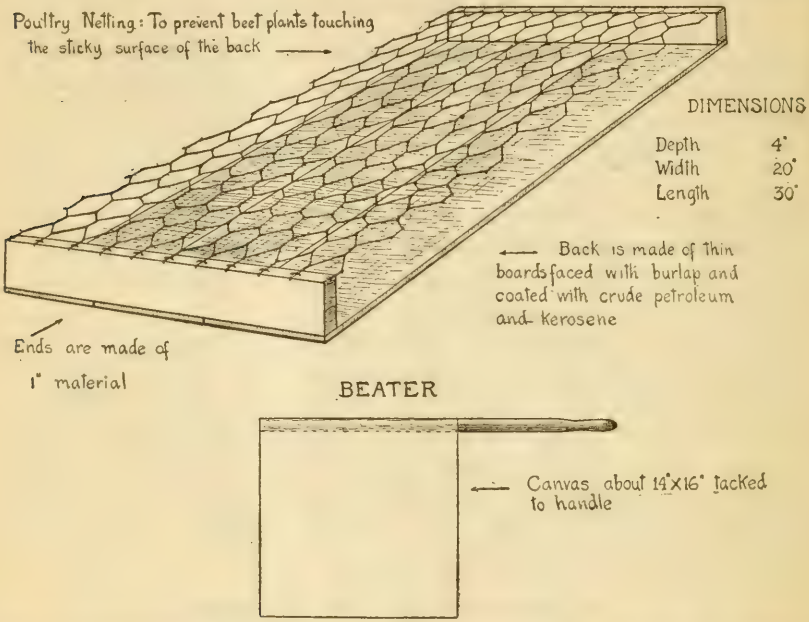

FIG. 2.—Sticky shield and beater for destruction of false chinch bugs on flowering beets. (Original.)

After the adult bugs have collected on a certain area, their destruction will usually end the damage by that brood. However, if others of the same or of succeeding broods are driven on later by the dying of adjacent vegetation, another application of remedial measures will be necessary. The more completely the earlier generations in a given year are destroyed, the less will be the damage by later generations during the same year; and the more thoroughly control measures are practiced during any year, the less is the danger of severe outbreaks the next year.

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FARMERS' BULLETIN

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.

"WHITE ANTS"[1] AS PESTS IN THE UNITED STATES AND METHODS OF PREVENTING THEIR DAMAGE.

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Specialist in Forest Entomology, Forest Insect Investigations.

CONTENTS.

INTRODUCTION.

The serious damage which "white ants," or termites, cause to a great variety of wood products, as well as to growing plants, can be prevented. This publication gives a brief account of these insects, their habits and damage, and shows how losses from this source may be avoided. The most serious damage by white ants is that caused to foundation timbers and the woodwork of buildings and to the material stored therein. Similar damage to other construction timber in contact with the ground is considerable, especially in the Southern States.

[1] The species principally treated herein are *Leucotermes flavipes* Kollar, *L. virginicus* Banks, and *L. lucifugus* Rossi.

Injury to living trees and shrubs, growing crops, or other vegetation is only occasional and local and usually occurs because the land has been cleared recently and there is much decaying wood and humus in the soil. There are several kinds of termites, or white ants, in the United States, but those which are best known and most commonly reported as injurious belong to three small, closely related, and very similar species [1] of more or less general distribution.

DESCRIPTION AND HABITS OF WHITE ANTS.

"White ants" are not true ants, although they are superficially antlike and live in colonies made up of different forms or castes and

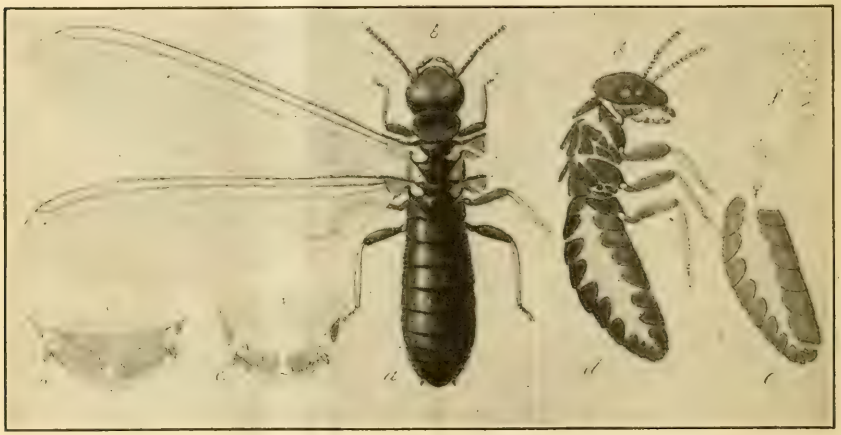

FIG. 1.—Winged forms of the white ant known as *Leucotermes flavipes:* *a*, Adult male; *b*, terminal abdominal segments from below; *c*, same of female; *d*, male, side view, somewhat inflated by treatment with ammonia; *e*, abdomen of female, side view; *f*, tarsus, showing joints and claws. *a*, *d*, *e*, Enlarged; *b*, *c*, *f*, greatly enlarged. *(Marlatt.)

are social insects. In these nests or colonies both wingless and winged mature individuals are produced. The brownish, or blackish, elongate, slender, antlike, sexed adults (fig. 1) with long white wings, unlike the other forms, have functional eyes and are able to endure full sunlight. These migratory males and females appear normally only once a year during a short period. The grayish-white, soft-bodied, wingless "workers" (fig. 2) are in reality the destructive form. These workers make the excavations and enlarge and extend the colony as this becomes necessary. They live underground and shun the light and are therefore rarely seen. The soft-bodied, wingless "soldiers" (fig. 3), which have an elongate, narrow head armed with long, slender, saber-shaped jaws, and the workers are the most

[1] *Leucotermes flavipes* Kollar, *L. virginicus* Banks, and *L. lucifugus* Rossi; order Platyptera, suborder Isoptera, family Mesotermitidæ.

numerous forms permanently present in the colony. Other forms in the colony are the reproductive individuals; in some colonies these consist of a single pair, the normal king (fig. 4) and queen (fig. 5), while in other colonies many supplementary nymphal (fig. 6) or larval types may be present. These reproductive forms never reach the size attained by those of certain species of termites in the Tropics and never lose the power of movement.

White ants are essentially wood destroyers and live in nests in the wood of dead trees, decaying logs, or stumps in the forest; in the

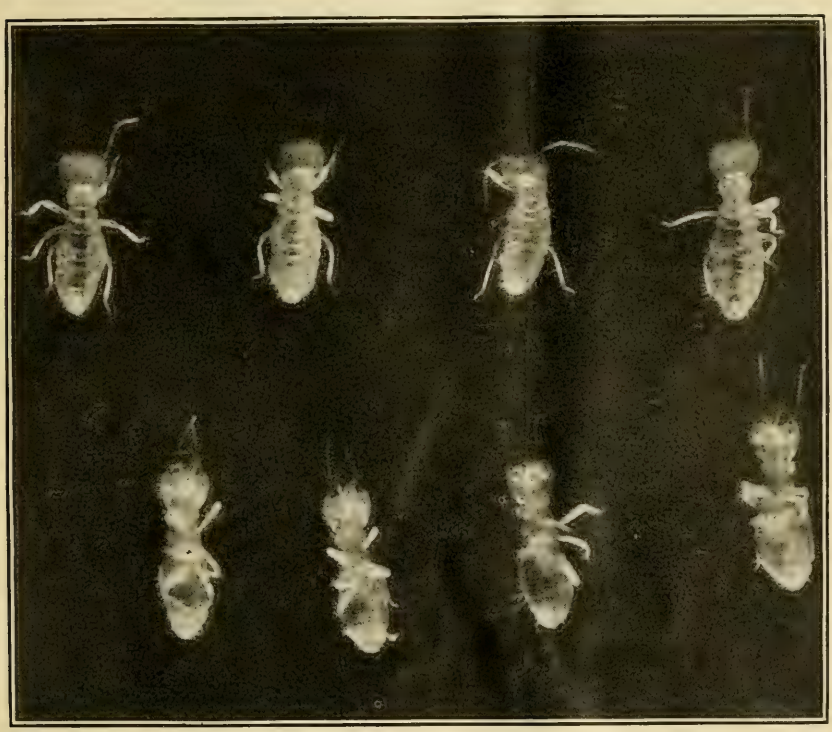

FIG. 2.—Mature "workers" of the white ant known as *Leucotermes flavipes;* etherized specimens. Enlarged nearly six times. (Original.)

foundation timbers of buildings, fences, or other structures of wood in contact with the ground; or in a labyrinth of underground passages in the earth, usually underneath wood or other vegetation. An average colony contains several thousand individuals. Owing to their subterranean habits and often countless numbers, it is sometimes very difficult to destroy them when once they are established in a building. Always coming up through underground galleries, they work in the interior of the wood and leave intact a protective outer shell, so that the damage is often unsuspected until beyond repair.

LIFE CYCLE OF WHITE ANTS.

There are three stages in the life of white ants; namely, the egg, the immature form (larvæ, or nymphs), and the mature individual (including workers, soldiers, and the various reproductive forms).

Egg laying occurs over a considerable period of time during the warm months in colonies out of doors, but in infested buildings where an even temperature is maintained, especially those occupied by man,

FIG. 3.—Mature "soldiers" of the white ant known as *Leucotermes flavipes;* etherized specimens. Enlarged nearly six times. (Original.)

the insects are active and egg laying may occur during every month of the year. The number of eggs laid by each reproductive form depends on its age.

THE SWARM.

At a certain season of the year the winged, sexed individuals migrate in large numbers from the parent nests to found new colonies. The season during which swarming takes place varies with the species

and the geographical locality, usually occurring in the spring or fall. There are often several swarms from the same nest, sometimes as many as four separate swarms, extending over a period of one month. In infested buildings the winged males and females usually swarm a month or more earlier than outdoors, and the more common species [1] was observed to swarm as early as the middle of February in infested buildings in Washington, D. C. Numerous urgent requests are received by the Department of Agriculture for information in regard to these "flying ants" in buildings.

FIG. 4.—Mature "king" of normal form of the white ant known as *Leucotermes flavipes;* several years of age. Etherized specimen, enlarged six times. (Author's illustration.)

FIG. 5.—True "queen" of the white ant *Leucotermes flavipes,* with wing stubs and chestnut-colored hard parts. Etherized specimen, enlarged six times. (Author's illustration.)

DAMAGE TO WOODWORK OF BUILDINGS AND TO OTHER TIMBER.

Damage to foundation timbers, flooring in basements, and other woodwork of buildings,[2] both in rural regions and in large cities, is common and often serious in the southern portions of the United States, especially in the South Atlantic and Gulf States. Injury of this type, however, has been recorded as far north as Manchester, N. H., and the shores of the Great Lakes (Benton Harbor, Mich.).

White ants live in wood which is in contact with, or can be reached from, the ground. The workers are able to travel comparatively long distances through subterranean galleries in search of wood and

[1] *Leucotermes flavipes* Kollar.

[2] Such injury in the Gulf States, Southwestern States, and California is caused also by *Calotermes* spp. (fig. 7) and in Florida by *Cryptotermes cavifrons* Banks.

in extending their colonies, and usually gain entrance to buildings from colonies outdoors. Infestation of the interior woodwork is effected from underground tunnels to and up through moist or decayed foundation timbers, flooring, or supports of porching or steps set in or on the ground.

Beams, such as joists, studding, stringers, and other foundation timbers in the basement or cellar, even though entirely inclosed or embedded in concrete, are but partially protected from attack by termites. In the settling of the structure, or in weathering, concrete is

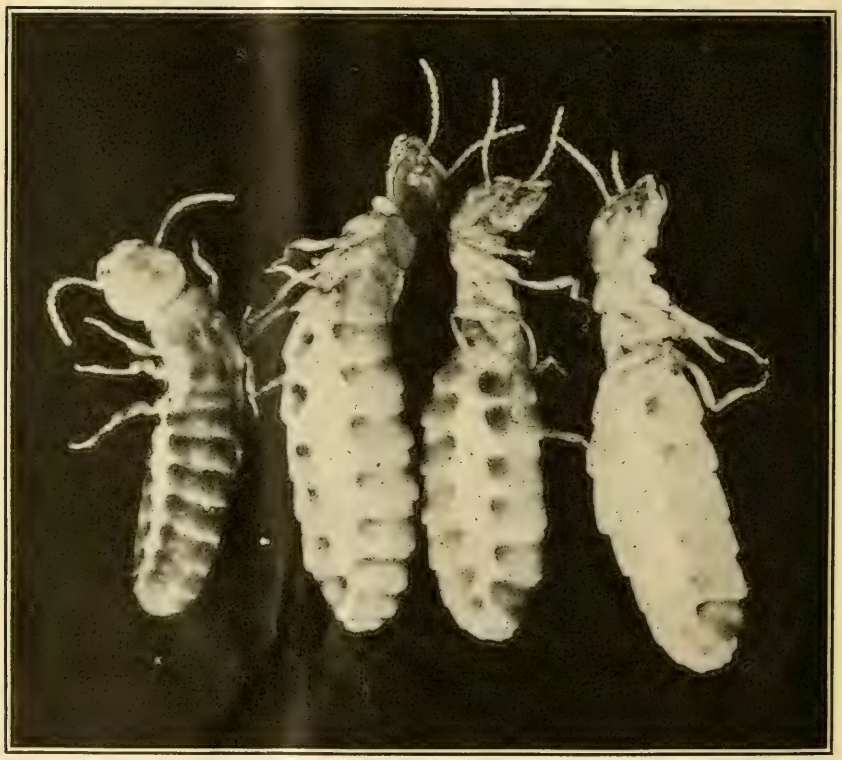

FIG. 6.—Supplementary nymphal reproductive forms of the European white ant *Leucotermes lucifugus*; one king and three queens. Colorado Springs, Colo. Enlarged 10 times. (Original.)

almost sure to crack and allow moisture and insects to enter. Furthermore, beams and joists put down in moist concrete decay rapidly and become exceptionally good breeding places for these insects; from such beams white ants carry their burrows up through the timbers to the first, second, and even third floors.

Flooring (fig. 8) and other stationary woodwork and furniture frequently become infested when the wooden beams are laid directly on the earth or in moist concrete; they are often reduced to mere shells, the interior being completely honeycombed. Termites usually follow the grain when working in solid wood.

Termites are able to extend their burrows throughout dry, hard wood and other dry substances far removed from the ground, and over impenetrable material, provided there is access to moisture

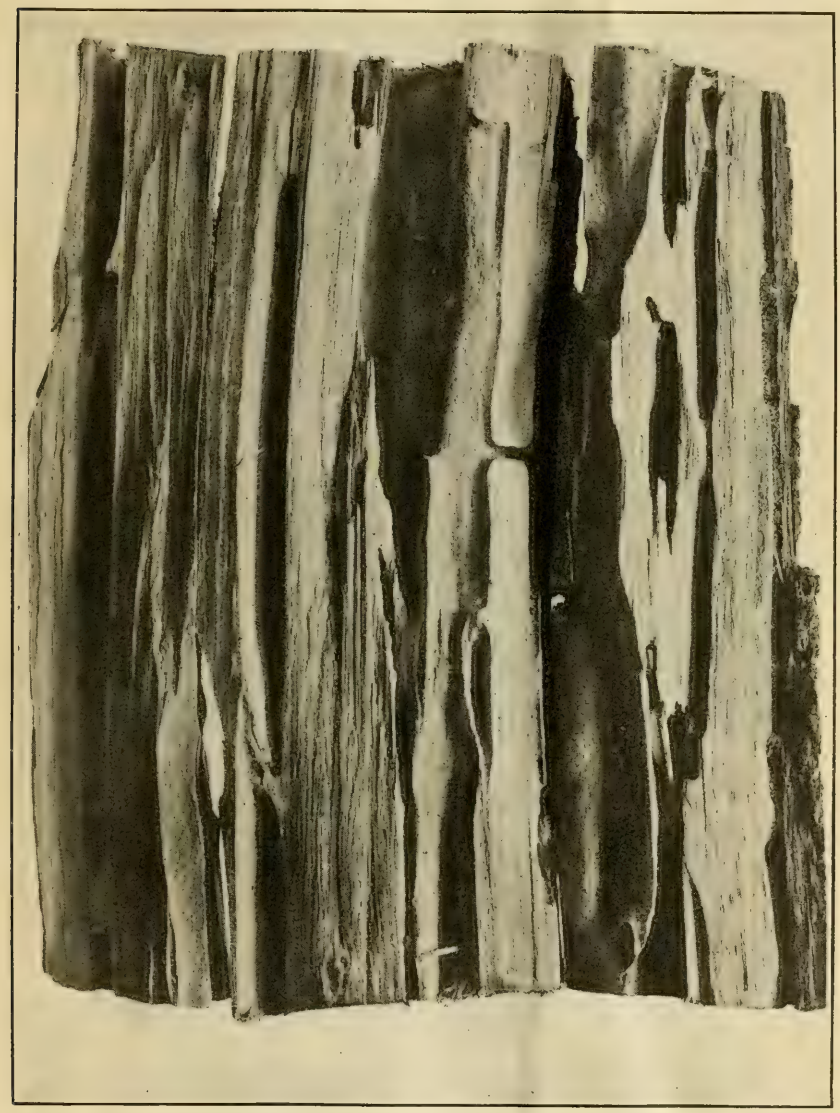

FIG. 7.—Work of a western white ant, *Calotermes* sp., in Mexican walnut. Catalina Mountains, Ariz. (Original.)

elsewhere, i. e., damp earth. They make use of a mixture of moist earth and finely digested, excreted wood in creating more favorable conditions of moisture and shelter while extending their galleries. White ants prefer to work in dark, warm, moist places.

Termites even pass over substances they can not penetrate, such as metal or stone, brick, or concrete foundations, by means of small shelter sheds or granular, earthlike tubes constructed of earth and excrement extended up from the ground.

Any wood construction in contact with the ground is especially liable to attack by white ants. Among these may be listed construction timber in bridges, wharves, and similar structures, telephone and

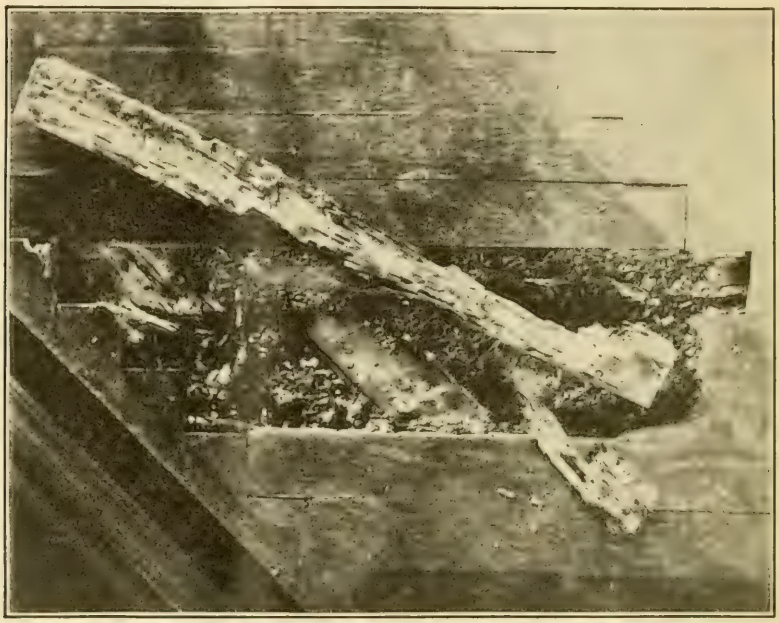

FIG. 8.—Oak floor honeycombed by white ant *Leucotermes flavipes*. Washington, D. C., July, 1915. Photograph by C. H. Popenoe. (Author's illustration.)

telegraph poles,[1] mine props, railroad ties, posts, lumber piled on the ground, wooden boxing for cables, cypress water tanks, etc.

DAMAGE TO STORED MATERIAL.

Of the stored material sometimes seriously injured or destroyed by termites may be mentioned wooden electrotype blocks and other wood products, books or papers in libraries or elsewhere (fig. 10), valuable documents (fig. 11), wood-pulp products, pasteboard, rolls of cloth and other fabrics, clothing, shoes and other leather products, as well as food stored on shelves or on the floors in dark, damp basements or cellars, or similar moist places where the ventilation is poor.

[1] In California damage to poles by *Termopsis angusticollis* Walker (fig. 9), and in the Gulf States by *Calotermes* spp. also occurs.

DAMAGE TO FRUIT, NUT, SHADE, AND FOREST TREES.

Termites occasionally injure living trees and shrubs. In Florida they have caused considerable damage to newly planted groves of orange trees, having eaten away the bark about the collar and root and completely girdled the trees. Similar damage by white ants has been recorded to other fruit trees, as apple, peach, pear, cherry, plum,

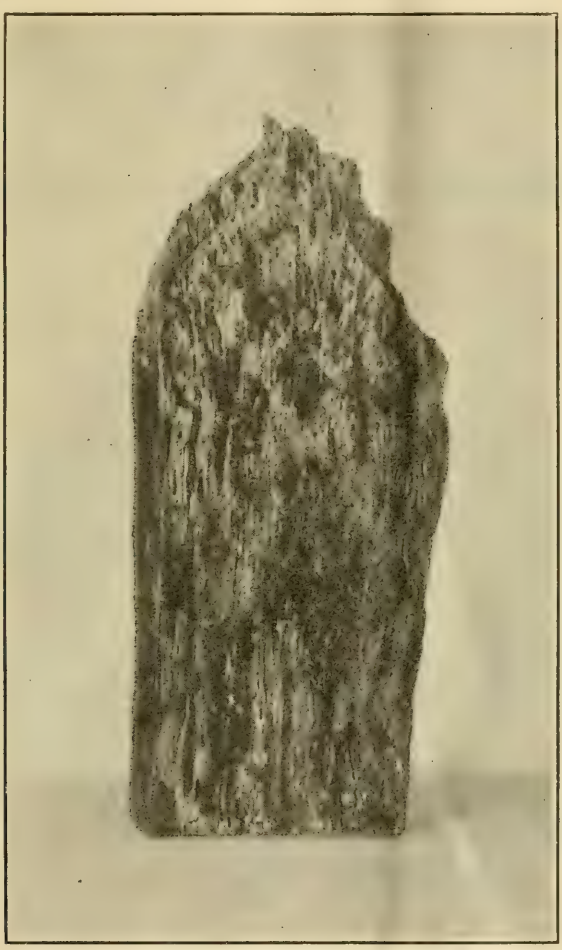

FIG. 9.—Work of a large western white ant, *Termopsis angusticollis*, in western yellow pine. Placerville, Cal. (Original.)

apricot, and lemon, especially in the Southern States and in California; and also to pecan, chestnut, and walnut trees. Such damage is more common in the new soil of recently cleared woodland containing old decaying stumps or much humus.

In cities and elsewhere, a great variety of shade trees are injured by white ants, the insects infesting the roots and the heartwood

at the base of injured trees. Sometimes the infested trees are plastered with earthlike tubes or galleries.

Particularly in the South, termites render insect, fire, and disease killed timber unmerchantable, unless the timber is utilized within a reasonable period after being killed. They also damage the roots and lower trunks of injured living trees.

DAMAGE TO FIELD CROPS AND GRAZING LAND.

In the Southern States white ants occasionally injure the stems and roots of a great variety of apparently healthy field crops, including both grain and truck crops, among which may be listed corn,

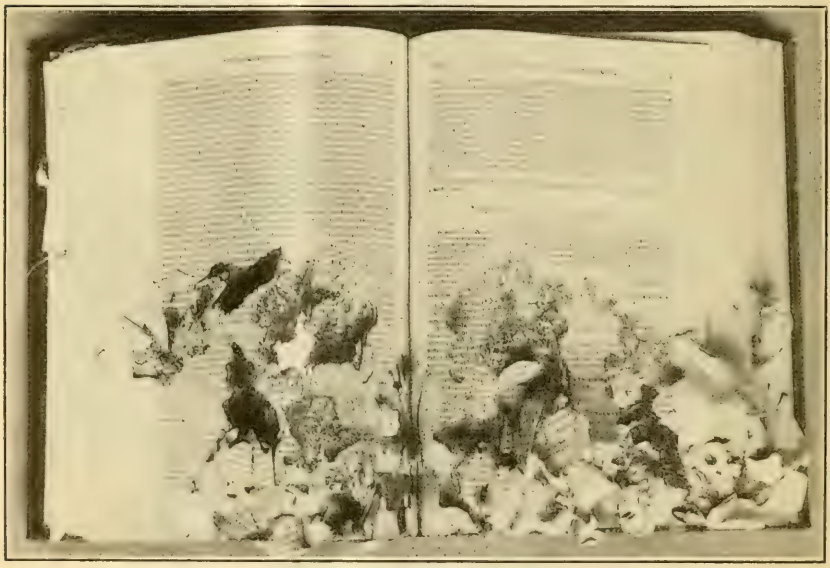

FIG. 10.—Book from library at Van Buren, Ark., ruined by white ants. June, 1915. (Author's illustration.)

cotton, sugar cane, rice, grasses, potatoes, and a great variety of garden vegetables.

Injury to corn in the prairie region of Kansas has resulted from the earlier presence of the insects in enormous numbers in the heavily sodded soil where they feed on the roots of the vegetation. Sometimes this injury to growing corn is due also to the method of plowing under old stubble.

In the prairie regions of Texas and Arizona a tube-forming termite[1] lives in the ground, feeding on the roots of grass and other vegetation, and is often found under and within dry cow dung and under stones. This species sometimes destroys the vegetation over large areas of grazing land. One of its characteristic habits is to cover

[1] *Hamitermes tubiformans* Buckley.

the stems and roots of vegetation with tubes of small diameter constructed of earth and excrement.

DAMAGE TO NURSERY STOCK, YOUNG PLANTATION STOCK, AND VINEYARDS.

There are numerous records of termite injury to young fruit and nut tree seedlings in nurseries, to other nursery stock, and to

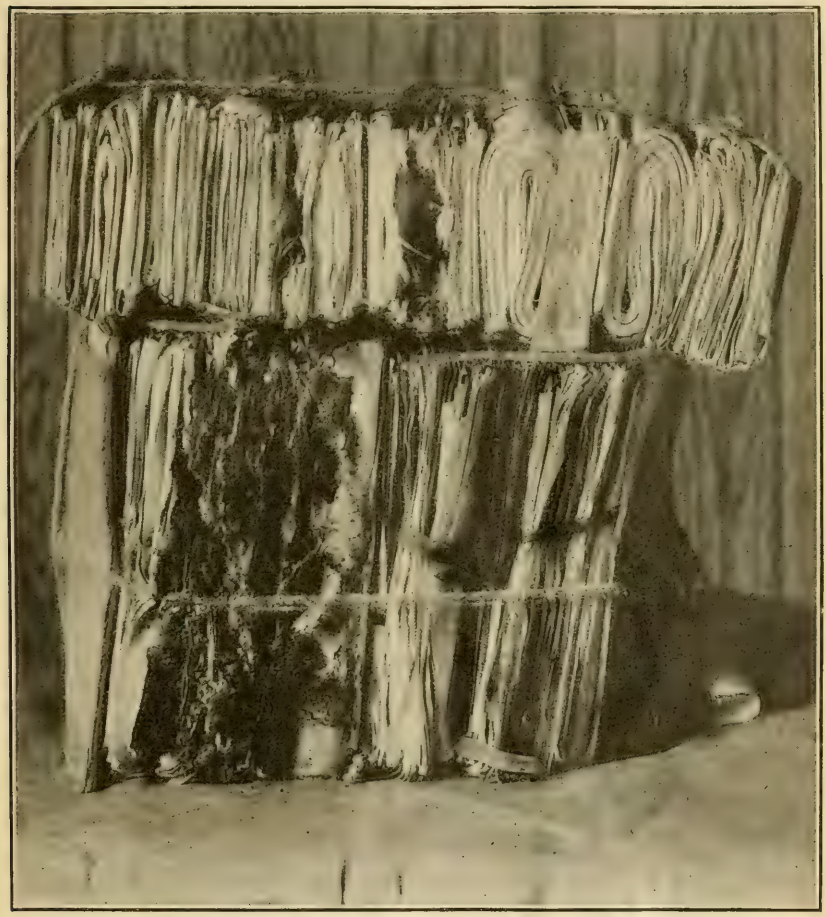

FIG. 11.—Damage by the white ant *Leucotermes flavipes* to bundles of old documents stored on tiers of wooden shelves standing on pine flooring in heated, damp, dark basement of an old building in Washington, D. C. Note how an earthlike mixture of moist earth and finely digested, excreted wood is carried into the mines of the insects in the bundles. If the connections of the termites with the ground or decayed wood, their source of moisture, be shut off, the insects perish. (Original.)

young trees planted in recently cleared ground or soil rich in humus. The injury, however, has been only occasional and not extensive. The stock is usually attacked at a scar, where the roots have been injured or cut off, or at a graft, as cleft-graft apple stock.

Injury by termites to vineyards has occasionally been recorded in North America. Usually only the old vines are attacked, or dead or injured parts. Signs of attack are sickly foliage or abortive buds, or the injury is observed at the time of cutting down to stock or grafting.

DAMAGE TO SHRUBS, FLOWERS, AND GREENHOUSE STOCK.

White ants injure a variety of shrubs, weeds, and flowers in gardens as well as in greenhouses. Heavily manured flower beds are a source of infestation to the stems of flowers as well as to the woodwork of houses. In greenhouses old label sticks, the wooden uprights supporting wooden benches set on or in the ground, and the wooden bench bottoms and plant pots are often attacked by white ants, and this leads to subsequent attack of the growing plants.

In the Greenhouse Insect Investigations of the Bureau of Entomology, carried on at Washington, D. C., records have been made of serious injury to many plants grown under glass, and control methods have been tried by Arthur D. Borden, who has found that heliotropes, begonias, bedding geraniums, carnations, chrysanthemums, and roses are seriously injured by white ants. One hundred and eighty out of 1,000 heliotrope plants were killed the first week after being potted from the seeding pans. As many as 75 white ants have been found in a 4-inch pot of heliotrope. The insects come up through the ground and form dirt galleries over the supports, or burrow up through the wooden bench legs and run galleries the full length of the wooden benches. They enter the soil through the drainage holes of the pots and eat out the main stalk of the root, killing the plant very quickly.

PROTECTION OF WOODWORK IN BUILDINGS.

PREVENTION OF THE DAMAGE.

Since white ants are difficult to eliminate from the woodwork of a building when once established, every precaution should be taken to prevent their gaining an entrance

In order to prevent the insects from reaching the woodwork of buildings from their nests in the ground, the foundations should, where possible, be entirely of stone, brick, or concrete, including the pillars in the basement or cellar. The walls, partitions, and flooring in the ground floor, basement, or cellar should also be of concrete. Wooden flooring can be laid over this concrete floor if more desirable. An air space should be left between the concrete floor and the wooden floor laid over it. Concrete floors should be laid on a gravel base which will prevent dampness and cracking. The points of juncture between concrete walls and flooring should be filled in by rounding off the concrete at these places, since cracks often occur where the wall and

floor join at right angles; termites often come up through cracks between walls and flooring.

The publications of the Department of Agriculture should be consulted in regard to the specifications for the proper proportioning, mixing, and placing of concrete.[1] Recent tests conducted by the Office of Public Roads and Rural Engineering have demonstrated the value of mixing a heavy mineral residual oil with Portland cement paste to form an admixture [2] almost perfectly nonabsorbent of water and therefore an excellent material to use in damp-proof construction, as flooring, etc. Where the various patent or noiseless floorings are used on the ground floor, they should always be laid over a concrete base, especially if they contain wood fiber as a constituent.

Bungalows or frame buildings in the country which have no cellar should be raised from the ground on stone foundations to a height which will allow light and air to penetrate beneath.

Where stone or concrete foundations are impracticable, timber impregnated with coal-tar creosote should be used. Untreated beams should never be laid on the earth nor imbedded in moist concrete, since they will rot, even if they do not become infested.

Beams in no case should be completely surrounded with mortar or brick; there should be an air space around the beams so as to permit air circulation. Beams should not be set *in* earth or *in* moist concrete but should be set *on* rock or dry concrete.

The supports of the woodwork of coal bins in basements or cellars should not be set in the ground but should rest on concrete. Window sills and frames in the basement or cellar should be laid over concrete, and the woodwork should not come in contact with the ground. There should be no untreated wood in contact with the ground through which white ants can come up from subterranean galleries. Complete dryness of foundation timbers and basement walls and flooring is an important means of rendering buildings safe from attack by white ants. Good subventilation should be secured; that is, a deep air space should be left between the ground and wooden flooring. If the flooring is to be of concrete, the concrete should be laid on a gravel base to prevent dampness. The supports of porches or steps should never be laid directly on the ground but should rest on rock or concrete.

In case of the plank platforms in front of suburban railroad stations, even if the planking be laid on the proper foundations the boards should not be joined closely together, but at least a ¼-inch space should be left between to allow light and air to penetrate and to prevent dampness and infestation by white ants. Often these

[1] The use of concrete on the farm. U. S. Dept. Agr. Farmers' Bul. 461, 23 p., 10 fig. 1915.
Concrete construction on the live-stock farm. U. S. Dept. Agr. Farmers' Bul. 481, 32 p., 24 fig. 1915.
[2] Page, L. W. Oil-mixed Portland cement concrete. U. S. Dept. Agr. Bul. 230, 26 p., 6 pl., 5 fig. 1916.

platforms are roofed over and the wooden pillars supporting the roof are sometimes raised slightly off from the planking on iron rests. This prevents dampness, decay, and attack by white ants at the base (fig. 12). In other cases these pillars are set on a concrete base to one side of the planking, where they are not affected if the wooden boards of the platform decay.

In the construction of greenhouses, iron frames and concrete work should be used in place of woodwork wherever possible, as this woodwork is often seriously injured by termites owing to the warm moist atmosphere maintained throughout the year. The wooden uprights supporting the wooden plant benches should never be set on or in the ground but should rest on stone, bricks, or concrete above the

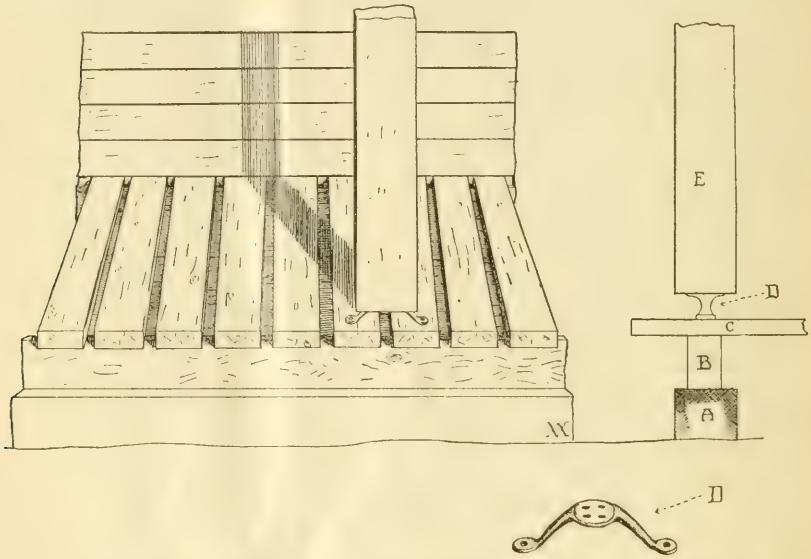

FIG. 12.—Properly laid platform planking and foundations for pillars, Falls Church, Va.: *A*, concrete base; *B*, stringer; *C*, planking; *D*, iron rest; *E*, pillar. (Original.)

surface of the ground. Where woodwork is necessary, wood impregnated with a 1 per cent solution of bichlorid of mercury should be employed.

All decaying wood in the vicinity of buildings should be removed and the breeding places of the insects destroyed.

Buildings on recently cleared woodland, unless the foregoing precautions are heeded, are especially liable to attack by white ants because of the presence of decaying wood and humus in the soil.

REMEDIAL MEASURES.

LOCATION OF DAMAGE.

As has been stated, it may be difficult to eliminate and stop further damage by white ants when once these insects have become established in the woodwork of a building. The approximate point of

entrance should be sought at once by careful examination of all woodwork in contact with the ground. The foundation timbers, such as beams and joists in contact with the ground, and other woodwork in the basement or cellar should be examined so that the point of entrance of the insects and the extent of the damage already accomplished may be determined. It may be necessary to tear up the flooring and other woodwork to do this. The foundation timbers and interior woodwork found damaged should be removed, and the ground where they were set drenched with kerosene oil.

The annual emergence of large numbers of the flying white ants is an indication that the woodwork is infested, and the point of emergence indicates the approximate location of the infested timbers. Even if the insects are not observed swarming, large numbers of the dead winged adults or the discarded wings usually will be found near by. Frass and earth thrown out of crevices through which the insects emerge are also evidences of their presence. Sometimes the insects plaster the surface of wood with earthwork which will disclose their presence.

When efforts are made to stop further damage by termites in buildings, it should be realized that their numbers may be constantly recruited from some undiscovered, outside, central colony. The destruction of the winged colonizing adults at the time of emergence, while beneficial in preventing the establishment of potential new colonies, will not eradicate the insects infesting the woodwork.

Another warning of the presence of termite infestation is branching shelter tubes of small diameter, constructed of earth mixed with finely comminuted wood, on foundation timbers or other woodwork (fig. 13), or over the surface of stone, brick, or other impenetrable foundation material (fig. 14) from the ground to the woodwork. Drenching the ground where these tubes originate with kerosene oil will afford relief.

SUBSTITUTION OF STONE FOUNDATIONS AND TREATED TIMBER.

It is very rarely possible to find and destroy the external colony. The main purpose therefore must be to prevent the insects from gaining further access to the woodwork from colonies in the ground. This may be accomplished by replacing untreated foundation timbers and other woodwork in the basement or cellar with stone or concrete, including stone columns or pillars to support the flooring above, concrete or tile flooring, and concrete walls and partitions in the basement or cellar. If it is not practicable to substitute stone foundations, foundation timbers in contact with the ground should be replaced with timbers impregnated with coal-tar creosote.

Since the insects may have entered the building from their subterranean galleries by means of the supports of porchings and steps set

in or on the ground, these last should be removed and the ground soaked with kerosene oil.

In some cases thorough and repeated drenching of infested timbers, where accessible, with kerosene oil may afford temporary relief and kill many of the white ants. Kerosene oil should be poured into the crevices through which the winged insects emerge and on the ground where the earthlike shelter tubes originate. Very rarely, however, is any permanent relief effected by these means alone.

In greenhouses iron frames and concrete work should, wherever possible, replace woodwork. The wooden uprights supporting the

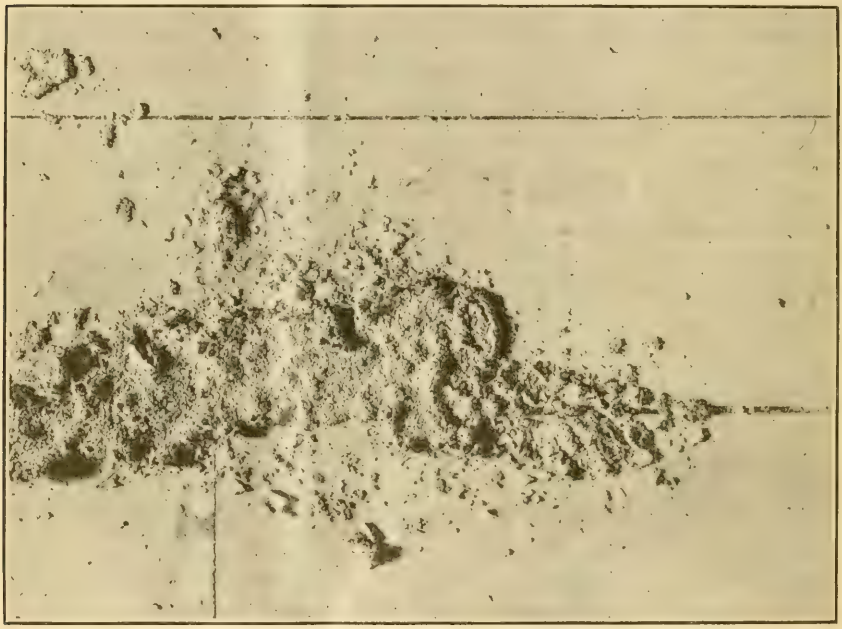

FIG. 13.—Earthlike shelter of the white ant *Leucotermes flavipes*, built on pine flooring in heated, damp, dark basement. The worker termites have come up through cracks between boards of the infested floor and made craterlike openings for the emergence of the winged, sexed adults. Note the shed wings on the floor. The swarm occurred February 14, 1916, in an old building in Washington, D. C. (Original.)

wooden plant benches should be sawed off, if set on or in the ground, and rested on stone, bricks, or concrete above the surface of the ground. Where woodwork is necessary, wood that is impregnated with a 1 per cent solution of bichlorid of mercury should be substituted. Wood impregnated with this preservative can be painted after treatment.

Poles, posts, construction timber, and other wood in contact with the ground should be treated with chemical preservatives to render the wood more resistant to attack by termites. Of the more superficial methods of preserving timber, brush or dipping treatments

with coal-tar creosotes and carbolineums have proved to be the most effective. The most permanent known practical method is to impregnate the wood under pressure with coal-tar creosotes Where it is impracticable to treat such timbers, as poles, posts, etc., to be set in contact with the ground, they should be selected from woods noted for durability and resistance to attack by white ants.

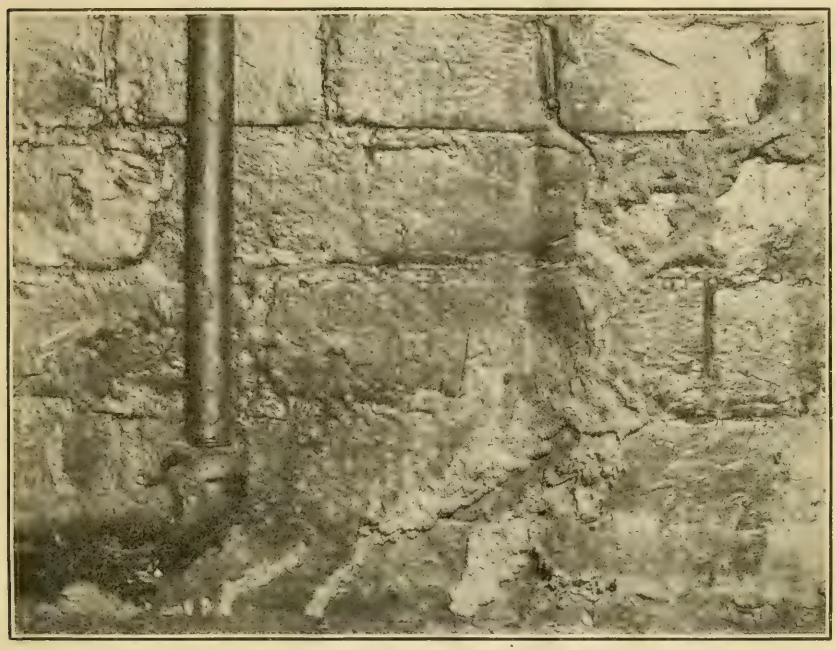

FIG. 14.—Earthlike shelter tubes of the white ant *Leucotermes flavipes*, constructed of earth mixed with finely digested, excreted wood, and built over brick wall in heated, dark, damp basement. These tubes extend through cracks between the basement pine flooring and the wall near a steam radiator. Note the granular structure. The insects use these tubes in passing over impenetrable substances and to protect them from the light in extending their galleries—in this case up to the next floor in an old building in Washington, D. C. (Original.)

PROTECTION OF STORED MATERIAL.

Injury to books, paper, documents, and other stored material or products is usually indirect, the insects as a rule burrowing through such material only where it is in contact with infested wood. Hence, if the insects are kept out of wooden structures, by the means already described, such damage can be prevented. Books, valuable documents, etc., should not be packed away in warm, unventilated chambers where they may become moist and moldy, and, therefore, particularly subject to attack by white ants. It should be borne in mind that termites are likely to be present in old buildings, even though their work has not been sufficient to attract attention. Once contact with the source of moisture (damp earth) is shut off, the

insects infesting stored material soon leave, die out, or can be killed by spreading out infested books, documents, and other stored material or products to dry in the sun or in an oven, or outdoors during cold weather. Temperatures over 160° F. will kill the insects.

PROTECTION OF LIVING TREES.

Owing to the subterranean habits of white ants, it is extremely difficult to prevent or remedy injury to living forest, fruit, or shade trees. Care should be taken that the trees do not become scarred near the base, in order to prevent heartrot and subsequent infestation. Clean forest, orchard, and horticultural management is to be recommended. Properly executed tree surgery [1] sometimes may be effective in repairing damage to valuable old trees. Dead and dying infested trees should be removed and burned. Prunings should be burned promptly.

PROTECTION OF NURSERY STOCK, VINEYARDS, AND FIELD CROPS.

Injury to nursery stock will be most serious on recently cleared land where there is abundant decaying wood. Such débris, in which the insects breed, should be removed. In general, the use of recently cleared land should be avoided in planting nursery stock. Care should be taken not to allow the roots to dry out before planting; such weakened stock is liable to attack. In the case of the pecan, it is recommended that two or three cereal crops be grown on newly cleared land before the young trees are set out. The use of commercial fertilizers instead of stable manure is suggested. Deep late-fall plowing should be of value in breaking up subterranean nests. The practice of better farming methods, with rotation of crops, will prevent damage to field crops.

In vineyards, care should be taken in pruning operations; all dead or diseased vines should be removed. All pruned areas should be painted with coal tar, and the prunings should be burned promptly.

PROTECTION OF FLOWERS AND GREENHOUSE STOCK.

In flower or truck gardens, especially those located near the woodwork of buildings, less stable manure should be used in order to protect, not only the building, but also the growing plants.

The very volatile liquid carbon bisulphid can be used to kill white ants in the soil if moist and not compact, if small holes be made near the infested plants and a small quantity of carbon bisulphid poured in and the hole immediately closed tightly with earth. Care should

[1] Collins, J. F. Practical tree surgery. *In* U. S. Dept. Agr. Yearbook for 1913, p. 163–190, pl. 16–22, 1914.

be taken in handling this inflammable and explosive fluid, and the fumes should not be inhaled.

In the experiments conducted by Borden, in the Department of Agriculture at Washington, an effective control was found in the use of a 5 per cent kerosene-emulsion solution.[1] In case the benches can not be replaced immediately on account of a certain crop, it has been found practical to soak the ashes or sand under the pots and the infested benches thoroughly with this solution. This may be done by removing the potted plants from a section of the bench, spraying that section, and moving the pots on the bench up to cover the treated area, thus exposing another section to be treated. Potted heliotrope and geranium have been treated directly with the 5 per cent kerosene-emulsion solution without injury to the plants and the white ants in the soil of the pots were all killed. This treatment should be given late in the afternoon and followed early next morning with a thorough syringing with water to wash the surplus oil out of the soil. It is important also to remove all infested pots promptly from the bench as soon as they are noticed and to destroy the white ants with kerosene emulsion.

The removal of decayed infested woodwork in greenhouses will prevent the plants from becoming infested in turn.

SUMMARIZED RECOMMENDATIONS FOR PROTECTION OF WOODWORK IN BUILDINGS.

HOW BUILDINGS SHOULD BE CONSTRUCTED SO AS TO BE "WHITE-ANT PROOF."

Where possible, make the foundation of buildings entirely of stone, brick, or concrete, including stone columns or pillars in the basement to support the floor above; make the walls and flooring in the basement or cellar also of concrete, and lay concrete floors on a gravel base. Fill in and round off points of juncture between concrete walls and flooring so that these will not meet at right angles.

Where stone or concrete foundations are impracticable, use timber impregnated with coal-tar creosote.

Never completely surround beams with mortar or brick; leave an air space around the beams to permit air circulation. Set beams *on* stone or *on* concrete, not *in* the earth or *in* moist concrete. Rest the supports of porches or steps on stone or concrete.

Lay basement window sills and frames over concrete and do not allow the woodwork to come in contact with the ground. Never sink

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[1] Kerosene emulsion formula:

Kerosene, 2 gallons.
Fish-oil soap, ½ pound.
Water, 1 gallon.

Method of preparation: Dissolve soap in hot water and pour in oil slowly while constantly stirring so as to emulsify.

Dilution: If 37 gallons of water be added to the above stock solution, it will give 40 gallons of 5 per cent kerosene emulsion.

untreated timber in the ground or in moist concrete; let there be no wood in contact with the ground through which the termites may come up from subterranean galleries.

Complete dryness of the foundation and basement walls and flooring is an important means of rendering buildings safe from attack; therefore, provide for air spaces between the ground and wooden flooring and lay concrete floors on a gravel base.

In greenhouses, replace woodwork, wherever possible, with iron frames and concrete work. Treat necessary woodwork, before use, with a 1 per cent solution of bichlorid of mercury.

HOW TO ELIMINATE WHITE ANTS ALREADY ESTABLISHED IN BUILDINGS.

Promptly examine the foundation timbers and other woodwork in the basement to determine the approximate point of entrance and the extent of damage already accomplished. After removing the damaged wood, drench the ground with kerosene oil.

Break up the earthlike shelter tubes by means of which white ants are sometimes able to pass over the surface of impenetrable substances in order to reach woodwork, and drench the ground beneath with kerosene oil.

Then replace damaged timber with rock, brick, or concrete; or, if this be impracticable, substitute, for the foundation, timbers treated with coal-tar creosote.

Since termites always require access to damp earth, shut off this source of moisture, and the insects will not be able to extend the galleries farther and will perish.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 763 NOVEMBER 29, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

ORCHARD BARKBEETLES AND PINHOLE BORERS, AND HOW TO CONTROL THEM.

By FRED E. BROOKS,

Entomological Assistant, Deciduous Fruit Insect Investigations.

INTRODUCTION.

This bulletin gives a brief account of the principal barkbeetles and related species that attack apple, peach, plum, and other orchard

FIG. 1.—Exit holes of the fruit-tree barkbeetle in sections of trunk of young apple tree. About natural size. (Original.)

trees and describes the methods most effective in controlling them. These troublesome insects are small beetles which belong to two

NOTE.—This bulletin is of interest to fruit growers generally, especially in the territory east of the Rocky Mountains.

groups: First, and most commonly injurious, the shot-hole borers or barkbeetles; second, the pinhole borers or ambrosia beetles. To the first group belong the fruit-tree barkbeetle[1] (fig. 2), which occurs throughout the United States east of the Mississippi River, in many localities farther west, and in Canada, and the peach-tree barkbeetle[2] (fig. 7), which has been found in the States of New Hampshire, New York, Pennsylvania, Maryland, the Virginias, North Carolina, Ohio, and Michigan, and in Ontario, Canada; to the second group belong the apple wood stainer[3] (figs. 14, 16) and a related species[4] (fig. 15), and the pear-blight beetle[5] (fig. 17), of the Eastern United States. The species which are the most generally distributed members of the two groups in the United States and those of greatest importance from the standpoint of injury to deciduous fruit trees[6] are discussed in the following pages. Each of them attacks several kinds of fruit trees, although the peach-tree barkbeetle appears to infest only the trees that bear stone fruits.

NATURE OF INJURY CAUSED BY SHOT-HOLE AND PINHOLE BORERS.

The shot-hole borers or barkbeetles burrow into the bark and slightly into the wood in both the larval or grub stage and the adult or beetle stage and, by extending their burrows in great numbers between the bark and sapwood, destroy that vital part of the tree known as the cambium. As a rule, sound, vigorous bark is not attacked, injury being confined to such trees as have had their normal health impaired by some other agency. Cases are not unknown, however, in which the beetles have multiplied greatly in diseased and dying wood and have then extended their attacks to near-by healthy trees, causing extensive loss. The female beetles, in entering the bark to deposit their eggs, and, also, all the newly transformed beetles in leaving their pupal quarters in the wood, make small but rather conspicuous round holes in the bark. Numerous punctures of this kind very frequently appear in trees within a short time after they have been seriously weakened or vitally injured by some cause not connected with these insects. On account of the fact that these entrance and exit holes are apt to attract the attention of orchard owners, it is probable that the loss of trees is sometimes attributed directly to injury by barkbeetles, when, in reality, death is due primarily to some weakening of the trees caused by root or crown dis-

[1] *Scolytus rugulosus* Ratz. [2] *Phlocotribus liminaris* Harris. [3] *Monarthrum mali* Fitch. [4] *Monarthrum fasciatum* Say. [5] *Anisandrus pyri* Peck.

[6] Another species, *Stenoscelis brevis* Boh., of somewhat similar appearance but belonging to another family of beetles (Calandridae), is frequently received from fruit growers who suppose it to be injurious. This insect is common in dead wood of apple and some other trees. The beetle is black and about one-eighth of an inch in length. The larva is white and has a row of minute black spots on each side. So far as is known at present this species does not feed in living wood and therefore does not occur in orchards of perfectly sound trees.

eases, overbearing, starvation, injury to roots or base of trunk by other insects, mice, or rabbits, injury by the San Jose scale, or some other cause more or less obscure.

The pinhole borers or ambrosia beetles, which are somewhat similar to the foregoing in size, color, and form, penetrate farther into the wood than do the barkbeetles, and, like them, prefer to attack diseased or dying trees. Beetles of this group sometimes bore into the twigs of live apple and pear trees, causing a dying back of the tips as though from twig blight. They have also been recorded as injuring nursery trees by boring into the trunk and causing that part of the tree above the point of injury to die.

THE FRUIT-TREE BARKBEETLE.[1]

HISTORY AND GEOGRAPHIC RANGE.

The fruit-tree barkbeetle, or shot-hole borer (fig. 2), probably was introduced accidentally into America from Europe some time pre-

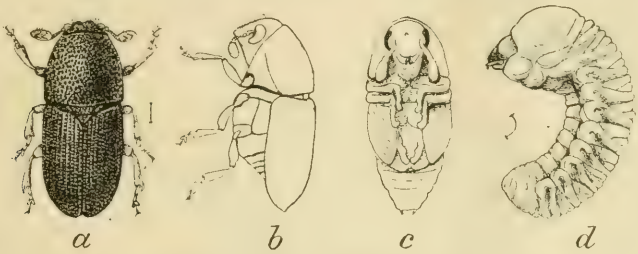

FIG. 2.—The fruit-tree barkbeetle (*Scolytus rugulosus*): *a*, Adult, or beetle; *b*, same in profile; *c*, pupa; *d*, larva. All enlarged about 10 times. (Chittenden.)

vious to the year 1877. The insect is now known to occur throughout practically all the United States east of the Mississippi River, and has become established in many localities to the west and also in Canada, although it does not appear at the present time to have reached the Pacific Coast States.

TREES ATTACKED.

The fruit-tree barkbeetle attacks and breeds in most of our cultivated deciduous fruit trees and in several species of uncultivated pome and stone fruits. The list of food plants is known to include apple, pear, plum, peach, cherry, quince, apricot, nectarine, wild cherry, chokecherry, wild plum, mountain ash, loquat, and service berry. Under favorable conditions multitudes of the beetles may develop in the wild trees mentioned and migrate in destructive numbers to near-by cultivated orchards.

LIFE HISTORY AND HABITS.

The adult, or beetle (fig. 2, *a*, *b*), is about one-tenth of an inch in length and of a dark brown or black color with dull reddish mark-

[1] *Scolytus rugulosus* Ratz.; order Coleoptera, family Scolytidæ.

ings on the legs, about the head, and on the tips of the wing covers. In the spring, from April to June, according to latitude, the beetles appear on suitable trees and begin to excavate brood chambers between the bark and sapwood. In preparing the chamber the female beetle gnaws a round hole, about one-twentieth of an inch in diameter, through the bark and then extends a slightly enlarged burrow (fig. 3, *a*), $1\frac{1}{2}$ or 2 inches in length, nearly or quite parallel with the grain of the wood. This burrow or brood chamber is made partly in the bark and partly in the wood, and during the process of its construction small niches are mined out on both sides, in each of which a minute white egg is deposited. A single female will produce, on an average, from 75 to 90 eggs.

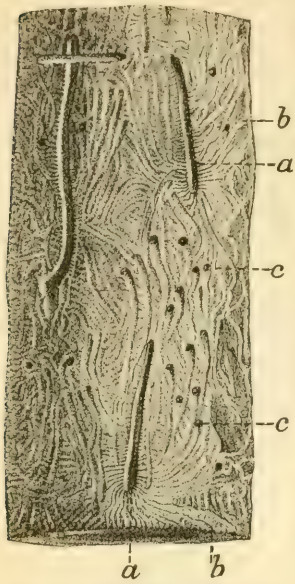

FIG. 3.—Galleries of the fruit-tree barkbeetle on twig under bark: *a, a,* Main galleries; *b, b,* side or larval galleries; *c, c,* pupal cells. Natural size. (Ratzeburg.)

The eggs hatch in 3 or 4 days. The small, footless, grublike larvæ are white with reddish heads and attain, when full grown, a length of about one-tenth of an inch. The larvæ (fig. 2, *d*) burrow between the bark and sapwood, first at right angles away from the brood chamber, and form centipede-like figures in the wood which are disclosed by removing the bark. (Fig. 4.) The larval burrows when

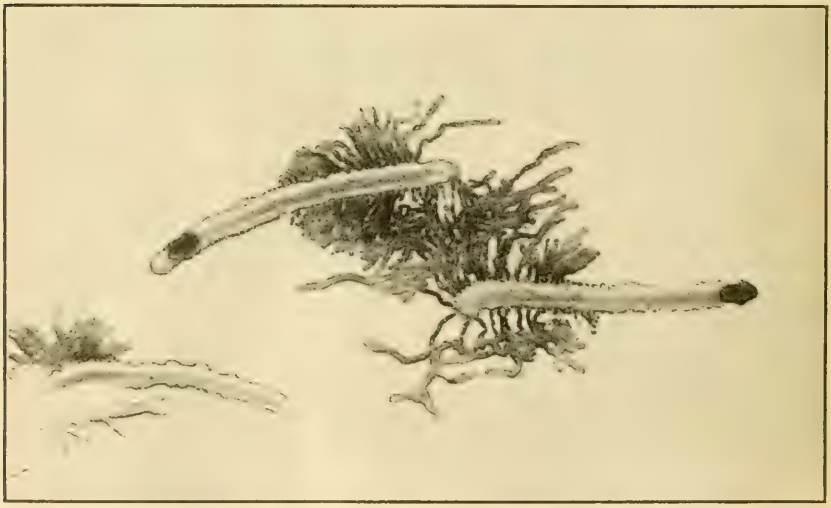
FIG. 4.—Galleries of the fruit-tree barkbeetle under apple bark, showing adult females in brood chambers. Enlarged. (Original.)

completed average 3 or 4 inches in length and are filled with dust-like frass of a reddish-brown color. After feeding from 30 to 36

days the larvæ attain full growth and pupate within specially constructed cells just beneath the surface of the sapwood.

The pupal period (see pupa, fig. 2, *c*) lasts from 7 to 10 days, and at its termination the beetles that have developed gnaw out through the bark, making their escape through small, round holes (fig. 1) similar to the entrance holes made previously by the females.

Within a few days after emerging these young beetles begin to deposit eggs, giving rise to a second brood of larvæ which feed in the trees during the latter part of the season. In approximately the northern half of the territory over which this barkbeetle is found the second-brood larvæ winter in the trees, pupating early in the spring following. In the southern part of the territory, however, these larvæ become adults before winter, escape from the trees, and deposit eggs, providing thereby for a third brood of larvæ. Thus, in the Northern States there are two generations of the insect annually, while in the South three and possibly four generations may occur within the year.

FEEDING HABITS.

Except in cases where the barkbeetles are excessively abundant, they do not normally attack and breed in healthy trees, neither do they feed and deposit their eggs in wood that is entirely dead. Trees that have been greatly weakened by unfavorable conditions, or that are in the act of dying, afford the most acceptable food for the beetles and their larvæ. Where there is a great quantity of dying wood, such as prunings and trees that have been injured by the San Jose scale, the yellows, freezing, or root troubles, the beetles will breed in great numbers, and after their supply of preferred food has been exhausted they will sometimes attack vigorous trees that may be growing in the vicinity. At first the attacks may not make much impression on sound trees, but a continuation of the injuries may eventually weaken the trees to such an extent that they become acceptable food for the larvæ, which can then develop within the bark, and after this the death of the tree is reasonably sure to follow very soon.

When healthy peach, plum, cherry, and other stone fruit trees are attacked, the flow of gum (fig. 5) will often check the entrance of the beetles and will prevent the development of larvæ in cases where eggs are deposited. The formation of gum at the wounds will diminish, however, as the tree is weakened, and after a period during which slight but numerous injuries have been inflicted by the beetles the condition of the tree may become exactly right for the deposition of eggs and the growth of the larvæ. The trunk, branches, and twigs of suitable trees are attacked and all the inner bark and the

surface of the sapwood converted to dust in a very short time by the primary wounds of the beetles and the more extensive burrows of the numerous larvæ. (See fig. 6.)

NATURAL ENEMIES.

Several kinds of four-winged insect parasites attack and destroy the barkbeetle larvæ, probably the most abundant and effective being a small species known technically as *Chiropachys colon* L. Minute nematode worms of an undetermined species have been found inhabiting the bodies of the larvæ, but to what extent, if any, they reduce the number of insects, has not been determined. Among the birds, woodpeckers remove many of the insects from infested trees, especially during the winter months.

FIG. 5.—Gum exuding from wounds on peach limb caused by the fruit-tree barkbeetle. Reduced. (Original.)

THE PEACH-TREE BARKBEETLE.[1]

HISTORY AND GEOGRAPHIC RANGE.

The peach-tree barkbeetle (fig. 7) is a native of America and has been recognized as an enemy of peach trees since about the year 1850. It first came into prominence as a supposed cause of the disease of peach trees known as "yellows," a supposition which was not borne out by subsequent investigations. The insect is very similar in form and habits to the fruit-tree barkbeetle, although it does not attack so great a variety of trees. Peach, cherry, and wild cherry are its principal food plants, although it is known to work on plum when no other food is available.

FIG. 6.—Twig of apple killed by the work of the fruit-tree barkbeetle. Natural size. (Chittenden.)

At the present time the species is known to occur in the States of New Hampshire, New York, Pennsylvania, Maryland, Virginia, West Virginia, North Carolina, Ohio, and Michigan,

[1] *Phlocotribus liminaris* Harris; order Coleoptera, family Ipidae.

and in the Province of Ontario, Canada. It is probable that it may be found in States other than those mentioned.

As a rule, this beetle, like the one described previously, prefers to attack diseased and dying wood, and the known cases of serious injury by it to healthy orchards are not numerous. There are records, however, of its doing great damage to peach orchards in Ohio, New York, and Ontario, and the history of the species indicates that where breeding conditions are favorable it may multiply and become at any time a menace to peach, and possibly cherry orchards.

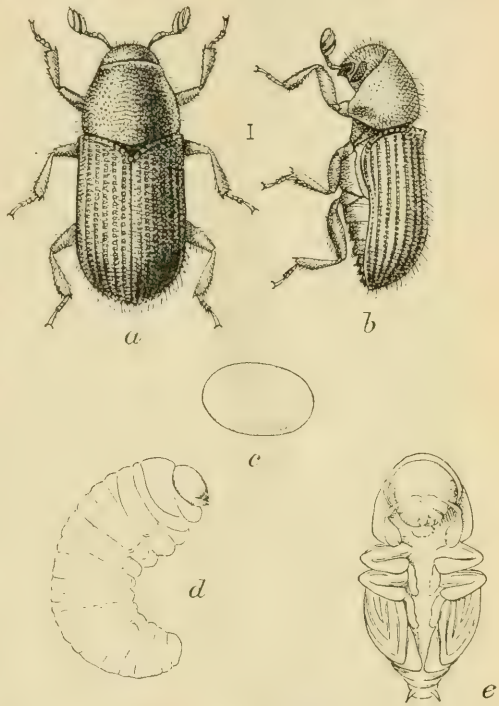

FIG. 7. — The peach-tree barkbeetle (*Phlocotribus liminaris*) : *a*, *b*, Adult, or beetle, dorsal and lateral views ; *c*, egg ; *d*, larva ; *e*, pupa. Greatly enlarged. (H. F. Wilson.)

LIFE HISTORY AND HABITS.

Unlike the fruit-tree barkbeetle, this insect winters in the tree as an adult. This adult, or beetle (fig. 7, *a*, *b*), is a little less than one-tenth of an inch in length and in color light brown to nearly black. Some of the beetles, which transform to the adult stage late in the fall, winter within their pupal cells in dead or dying trees; others, which transform earlier in the fall, leave the host tree and bore into healthy or unhealthy trees, forming hibernation cells just beneath the outer layer of bark. These hibernation cells are made at the inner terminus of burrows averaging about half an inch in length. Often great numbers of such burrows are made in growing trees, and during the following season there will be a copious exudation of gum from the numerous wounds similar to that caused by the fruit-tree barkbeetle (see fig. 5). The beetles, after leaving their hibernation quarters in the spring, make short burrows in healthy trees, either to obtain food or in an attempt to form brood chambers. The constant flow of sap from such wounds eventually weakens the trees to such an extent that brood chambers can be constructed without interference from

gum formation, after which the larvæ make short work of the trees.

The beetles leave their hibernation cells early in the spring and migrate to other trees, brush heaps of prunings, or any suitable wood wherein eggs can be deposited. The female bores into the bark, forming a hole very similar to that made by the fruit-tree barkbeetle, but distinguished from it by the particles of excrement, held together by fine threads of silk, which partly fill the mouth of the burrow or hang therefrom. The brood chamber (see figs. 8, 9) may be anywhere from 1 to 2½ inches in length. It may be told at a glance from that of the species described previously by the fact that almost invariably it is made to cross the grain of the wood transversely, instead of extending parallel with it, and that there is a short side tunnel branching from the main chamber near the inner end. This side branch enables the female to turn around within the burrow and is occupied by the male at the time of mating.

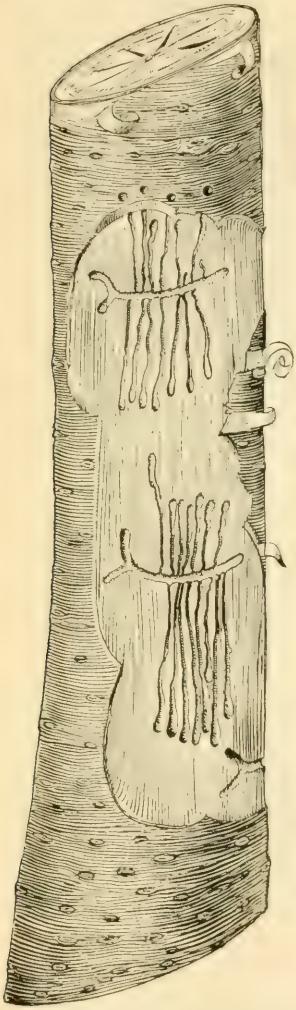

Fig. 8.—The peach-tree barkbeetle in wood of peach tree: Brood chambers and larval galleries. (H. F. Wilson.)

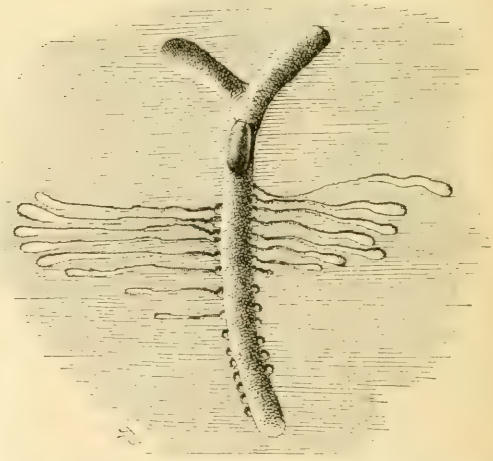

Fig. 9.—The peach-tree barkbeetle: Brood chamber with egg pockets and larval galleries in wood of peach tree. Lakeside, Ohio, May 18, 1908. Enlarged. (H. F. Wilson.)

The small, white eggs (fig. 7, *c*) are deposited in little pockets excavated from the walls of the brood chamber (see fig. 9), from

80 to 160 eggs being placed by a female in a single chamber. Eggs (fig. 7, *c*) from the first generation of beetles require from 17 to 20 days to hatch. The larvæ (fig. 7, *d*) bore at right angles away from the brood chamber, forming burrows from 1½ to nearly 3 inches in length. They are white, often with a pinkish cast due to the contents of the digestive tract, and have a yellowish head and darker mouth parts. In from 25 to 30 days they attain full growth and then pupate within the bark. From 4 to 6 days are passed in the pupal stage (fig. 7, *e*), after which transformation to beetles takes place. The adults of this generation issue about midsummer (see fig. 10) and provide eggs for a second generation, the beetles of which appear in the fall and hibernate as has been described. During the summer and fall the two generations overlap so that all stages of the insect may be found in trees at one time.

FIG. 10.—Exit holes in peach limbs made by adults of the peach-tree barkbeetle. Natural size. (Original.)

CONTROL OF THE FRUIT-TREE AND PEACH-TREE BARKBEETLES.

The first and most important point in connection with the control of these two species of barkbeetles is the elimination of breeding places. As has been shown, both species breed only in unhealthy wood, and where there is an abundance of such wood they will multiply in numbers limited only by the food supply. Trees and branches affected as follows have been observed to be favorite breeding places: Trees dying from neglect and starvation, from attacks of the San Jose scale, infection of "yellows," injury to roots and base of trunk by mice and rabbits, injury by blight and sun scald, and other diseases of roots, trunk, and branches, and injury by round-headed apple-tree borers; trees whose branches have been broken down by storms or loads of fruit, or any agency or condition that will cause unhealthy or dying wood. (See figs. 11 and 12.) Such wood should always be eliminated, either by restoring it through

proper treatment to a normal and healthy condition or by burning. Not only must such wood be guarded against within the orchard, but a lookout should be maintained of land adjacent to orchards.

FIG. 11.—Branches of apple tree broken by overbearing. The fruit-tree barkbettle was breeding in great numbers in the broken branches. (Original.)

where sickly seedling apple, peach, wild cherry, wild plum, serviceberry, crab apple, or other trees susceptible to infestation may form breeding centers for the beetles. Where all such breeding places can

be removed the danger of attacks by the beetles on healthy trees will be reduced to the minimum.

Trees of stone fruits, like peach, plum, and cherry, which are infested and from which the gum still exudes may often be saved

FIG. 12.—Branches left lying on the ground under a top-worked apple tree. Numbers of the fruit-tree barkbeetle were breeding in these branches. (Original.)

by the prompt application of remedies. They should first be cut back severely and then the soil about them cultivated and dressed liberally with barnyard manure or commercial fertilizer. This will stimulate growth and assist the tree in overcoming the injury. A thick

coat of whitewash (fig. 13) should then be applied. In cases of serious infestation it may be necessary to apply as many as three

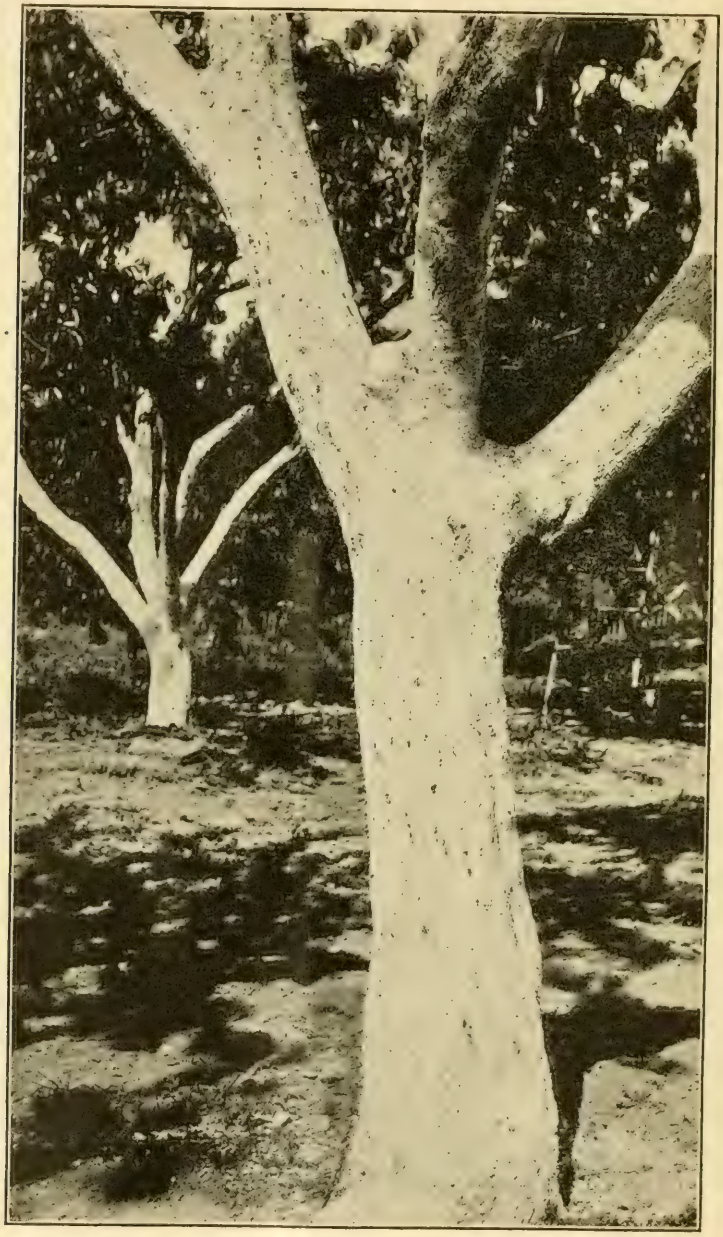

FIG. 13.—Peach trees treated with whitewash to combat the fruit-tree barkbeetle. (Original.)

coats of the whitewash during the season—one early in the spring, another about the middle of summer, and a third in the fall. If

the whitewash is mixed thin enough for application with a spray pump, two sprayings made about the same time will be necessary to supply a protective covering to the bark. If the mixture is made thicker, a single coat applied with a broom or brush will be sufficient for one time. The addition of a handful of table salt to each pail of whitewash will render the application more adhesive. Good results have been obtained by mixing a pint of crude cresylic acid with each 10 gallons of the whitewash.

The whitewash will not kill the insects already in the trees, but if a solid coat is maintained on the bark it will prevent in a large measure the laying of additional eggs and enable the trees, by the help of cultivation and fertilizers, to recover from the injury.

Many other washes, paints, and sprays have been tested against these insects, but when the cost of material, simplicity of preparation, and effectiveness are considered, nothing has been found that can be recommended as preferable to whitewash when prepared and used as directed above.

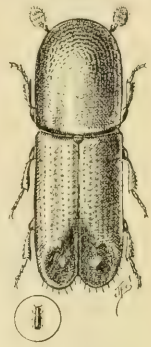

FIG. 14. — The apple wood-stainer (*Monarthrum mali*): Adult, or beetle. Much enlarged — natural size in small circle. (Original.)

THE APPLE WOOD-STAINER.[1]

The small wood-boring beetle known as the apple wood-stainer (fig. 14) derives its name from the fact that it stains the walls of its burrows black by propagating thereon a moldlike fungus on which it and its larvæ feed. This interesting habit is possessed by several related species, and the name "ambrosia beetles" has been given to the group on that account. Frequently the wood surrounding the burrows is stained a dark color as a result of the fungous growth.

The adult apple wood-stainer (fig. 14) is about one-tenth of an inch long and is reddish-brown to nearly black. In form it is cylindrical and slender, and it does not differ greatly in appearance from the barkbeetles described previously. A score or more of food plants have been recorded. These include forest and orchard trees, casks in which wine and other liquids are stored, and manufactured mahogany lumber. Among fruit trees it is known to attack apple, plum, cherry, and orange. About 50 years ago it attracted attention as an enemy of apple trees in Massachusetts, where it is said to have riddled the trunks of many young trees. Associated with this species

[1] *Monarthrum mali* Fitch; order Coleoptera, family Ipidae.

is found another, *Monarthrum fasciatum* Say (fig. 15) of similar appearance and food habits.

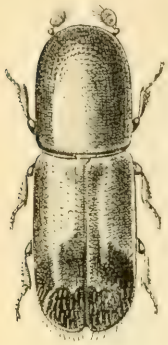

FIG. 15.—*Monarthrum fasciatum:* Adult, or beetle. Much enlarged. (Original.)

The female beetle bores through the bark and into the wood for a short distance and deposits her eggs. Later the short larval galleries are constructed outward from the main gallery made by the parent beetle. (See fig. 16.) Breeding takes place only in diseased, dying, girdled, and felled trees.

The insect is not a common orchard pest, but should it occur at any time in injurious numbers the remedies recommended herein for barkbeetles may be resorted to.

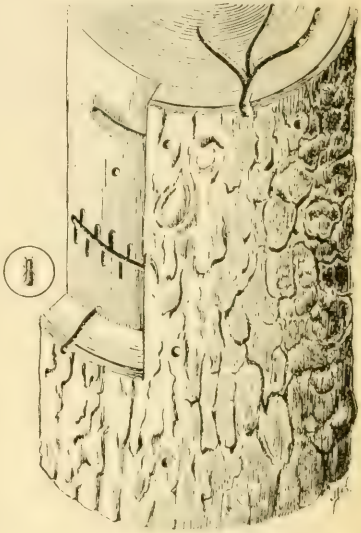

FIG. 16.—Work of the apple wood-stainer (*Monarthrum mali*) in apple wood. Beetle, approximately natural size, at left. (Original.)

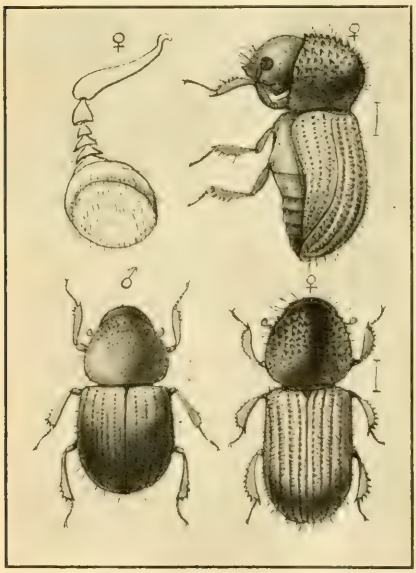

FIG. 17.—The pear-blight beetle (*Anisandrus pyri*): Adults, or beetles, and enlarged view of antenna of female beetle. All much enlarged. (Hubbard.)

THE PEAR-BLIGHT BEETLE.[1]

The pear-blight beetle (fig. 17) has been the cause of occasional injury to fruit trees for many years. It bores into the twigs and branches of apple, pear, peach, and plum trees and causes a dying back of the wood, the injury resembling that of the bacterial disease common on apple and pear, known as pear blight or twig blight. The insect also attacks the trunks of trees and is not confined to orchards, but infests a number of hardwood forest trees, and at least

[1] *Anisandrus pyri* Peck; order Coleoptera, family Ipidae.

one cone-bearing tree. Like the other species considered in this paper, it prefers to work in diseased and dying wood, although, as has been indicated, healthy trees are sometimes attacked. The species is distributed widely in the eastern part of the United States.

The female beetle (fig. 17, upper and lower right) is about one-eighth of an inch in length, of a dark-brown color, and has the head hidden from above by the projecting front of the thorax. The male beetle (see fig. 17, lower left) is only about half as large as the females. The adult female, when attacking twigs, usually makes her entrance at the base of a bud. The burrow (fig. 18) extends to and around the pith and has a number of short side branches running with the grain of the wood. Eggs are deposited loosely in the burrow and the larvæ feed on the ambrosia fungus which is propagated on the walls. The larvæ transform to adults within the burrow made by the parent beetle and issue from the tree through the entrance hole. Small branches are killed by these burrows, but when the beetles enter large branches or the trunks of trees the injury is not serious, and, as has been stated, more often than otherwise only unhealthy wood is entered. Injuries caused by twig blight and by these beetles are sometimes similar in appearance, but there is no relationship between the two troubles, and orchardists should be able to distinguish the insect injury from the blight by a close examination of the twigs.

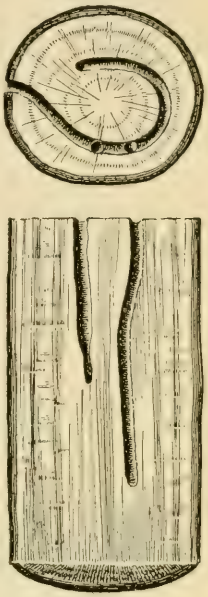

FIG. 18.—Gallery of the pear-blight beetle in poplar twig: Upper figure, transverse section; lower figure, longitudinal section. (Marx.)

Where remedial measures are called for, the methods recommended for use against the other species described herein should be adopted, with the additional precaution of cutting out and burning the infested twigs.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 766 NOVEMBER 20, 1916

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

THE COMMON CABBAGE WORM.[1]

By F. H. CHITTENDEN, *Entomologist in Charge of Truck-Crop and Stored-Product Insect Investigations.*

INTRODUCTORY.

The most destructive of the many insect and other enemies of cabbage and related crops over the United States generally is the larva or caterpillar of the imported cabbage butterfly (figs. 1, 2), sometimes called the white butterfly or rape butterfly, a familiar object to nearly everyone. This caterpillar, the imported cabbage worm, is well known to farmers throughout this country and in the Old World as well, and the butterfly is generally recognized by the farmer as the parent of the "worms."

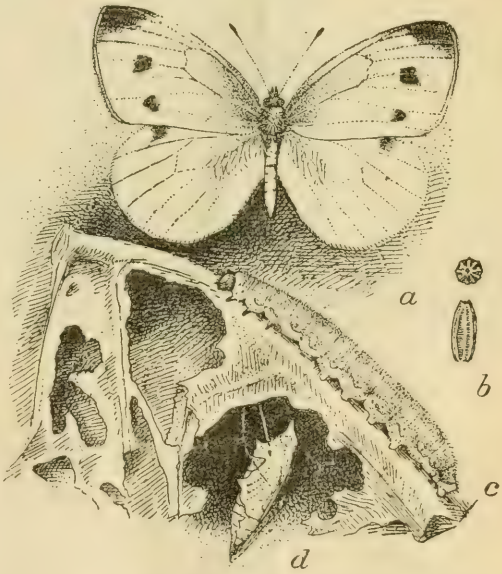

FIG. 1.—The common cabbage worm (*Pontia rapae*): *a*, Female butterfly; *b*, above, egg as seen from above; below, egg as seen from side; *c*, larva, or "worm," in natural position on cabbage leaf; *d*, suspended chrysalis. *a*, *c*, *d*, slightly enlarged; *b*, *more enlarged*. (Author's illustration.)

DESCRIPTIVE.

THE CATERPILLAR.

This cabbage worm is velvety green, about the same color as the cabbage on which it feeds. There is a faint yellow stripe down the middle of the back and a row of yellow spots along each side in line with the spiracles or breathing

[1] *Pontia rapae* L.; order Lepidoptera, family Pieridae.

NOTE.—This bulletin is intended to assist cabbage growers to control one of their most troublesome pests.

pores. The surface of the body, if viewed through an ordinary hand lens, is seen to be somewhat rough and finely dotted with small black spots. It measures, when full grown, about an inch and a fourth in length, presenting the appearance shown in figure 1, *c*. It differs from the cabbage looper,[1] another caterpillar found on such crops, in having five pairs of prolegs (unjointed hind legs) instead of four.

THE BUTTERFLY.

The butterfly (fig. 2) has a wing expanse of nearly 2 inches. It is white, marked with black near the tips of the forewings, as shown in figure 1, *a*, which represents the female. In the female there are two conspicuous black spots on each forewing, whereas the male (fig. 2) has only one. Each sex has a corresponding smaller black spot at the front edge of the hind wing. The body of the female is

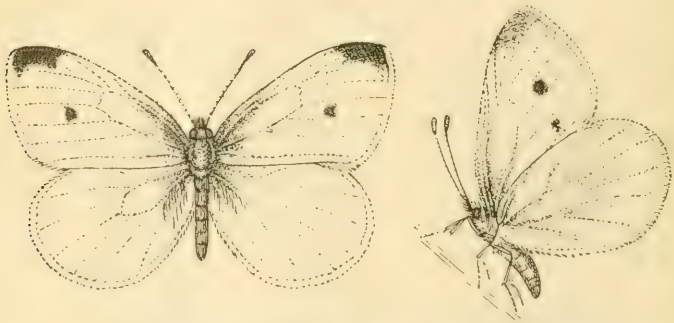

FIG. 2.—The common cabbage butterfly: Male, wings spread at left, wings folded at right. Somewhat enlarged. (Author's illustration.)

whitish, but that of the male is usually darker above. The male is generally the smaller. The underside of the hind wing is a uniform straw yellow of satiny aspect, and there are generally two black spots showing through in both sexes.

THE EGG.

The eggs are turnip-shaped, pale yellowish, and strongly ribbed (fig. 1, *b*), and may be seen readily with the unaided eye. They are deposited singly, usually on the underside of the outer leaves of cabbage and their other food plants.

THE CHRYSALIS.

When the caterpillar or "worm" becomes full-grown it attaches itself to a cabbage leaf or other near-by object by means of a thread-like girdle of silk, and often within the same day transforms to the chrysalis (fig. 1, *d*). The chrysalis is of variable color, being

[1] *Autographa brassicae* Riley.

influenced in this respect by the object upon which it is fastened. The color thus varies through dirty gray to yellow, green, and dark gray. The length of the chrysalis is a little less than three-fourths of an inch.

NATURE OF INJURY.

This cabbage worm has been rightly termed the bane of the cabbage grower and the dread of every careful cook and housewife. It begins work early in the season; the principal damage is therefore to young plants (fig. 3), and accrues through the necessity of replanting, with attendant increase in cost of production, due to additional labor, cost of stock, and delay in getting the early or better prices in the market. After riddling the outer leaves, which remain afterwards

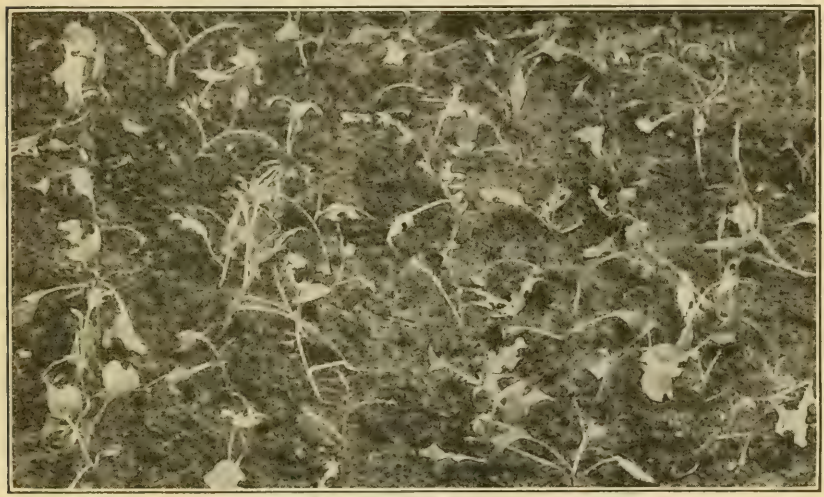

FIG. 3.—Cabbage seedlings grown in cold frames, showing injury by common cabbage worm. This necessitates replanting and additional labor, and causes delay in getting cabbage on the early market. (Original.)

attached to the stalk, the caterpillar attacks the tender inner leaves as they form, frequently secreting itself in the immature heads, where it is difficult to reach it with insecticides, and rendering the cabbage unfit for food because of the abundant dark green excrement which it deposits. As a result, cabbages before being sent to market must be examined carefully and the damaged leaves removed. Before cooking it is frequently necessary to tear the heads apart to insure that no disgusting worms are concealed within, and even after the vegetable is prepared for the table there is danger of an admixture of animal matter with the vegetable food. In cool weather the caterpillar often feeds freely exposed on the surface of the leaves in the sunshine.

Frequently the caterpillar bores into the center of the cabbage, attacking what is commonly known as the "heart," and then the entire head is worthless for market. Figure 4 illustrates this form of injury. Seedling cabbage grown in cold frames is also often damaged. Injury of this nature may be very serious, many of the plants being a complete loss, while the remainder make poor growth. Figure 5 illustrates an unusual form of damage in which the insects occur in such numbers as to congregate on a single leaf and ruin it

FIG. 4.—Cabbage showing severe injury by the common cabbage worm. This cabbage plant will never make a marketable head. (Original.)

in a very short time. This illustrates complete defoliation, and also is an indication of the sluggish habits of the larvæ during resting periods.

As early as 1869, when this cabbage worm was confined to limited areas in Canada, New England, and New York, it did great damage. At St. Albans Bay, Vt., in that year it caused the total destruction of a crop of 3,000 cabbage plants. The worms made their appearance

about the 1st of September, and there were from 10 to 50 on a head. The Abbé Provancher estimated the same year a loss of $240,000 in the vicinity of Quebec alone. One farmer near Montreal lost in a single season over 12,000 heads of cabbage. The following year in some places about New York City, where the insect had appeared only the year before, the entire crop of cabbage and cauliflower was destroyed. The loss in this case was estimated at half a million dollars.

Owing to the fact that during recent years arsenicals have been very generally used to control the cabbage worm, there are now few instances in any part of this country of the total destruction of crops of cabbages as was formerly often the case. Nevertheless a conservative estimate would place the present annual loss from this pest to cabbages alone (not including cauliflower and other related crops) at $1,300,000, or one-tenth of the entire crop.

FIG. 5.—Cabbage leaf completely defoliated by seven common cabbage worms. Slightly enlarged. (Original.)

ORIGIN, SPREAD, AND PRESENT DISTRIBUTION.

The imported cabbage butterfly was introduced from Europe, and was first recognized from a capture at Quebec, Canada, in 1860. It was not seen again until two years later, in the same locality. After a lapse of several years it was reported at intervals from other portions of Canada. In 1865 its first appearance in the United States was noted in Maine; the following

year, in northern New Hampshire and Vermont. In 1868 it had reached New York, and soon thereafter began to attract attention in new localities. In 1875 it appeared in Cleveland, Ohio, and two years later in Illinois. In 1880 it had penetrated southward to the Gulf States. This distribution has continued until now the species is known in practically every State in the Union. It appears to

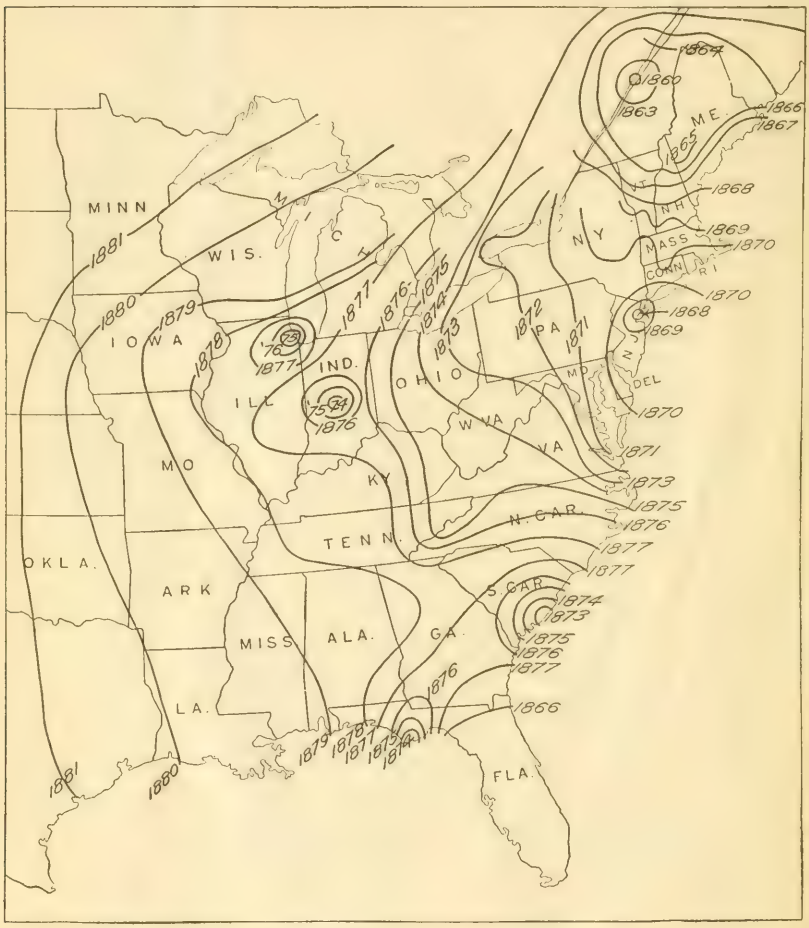

FIG. 6.—Map showing spread of common cabbage butterfly from 1860 to 1881. (Adapted from Scudder.)

favor no particular part of the country, being as destructive in the Gulf region as in Canada and New England. In the Western Hemisphere this butterfly ranges from the Atlantic to the Pacific, in most localities between the thirtieth and sixtieth degrees of latitude.

The accompanying map (fig. 6) shows approximately how this species has spread, chiefly by flight, according to the opinion of the

late Dr. S. H. Scudder, who was the highest authority on American butterflies. The westward spread has not been followed carefully.

FOOD HABITS.

The imported cabbage worm feeds on all forms of cruciferous plants, is particularly fond of cabbage and cauliflower, and is somewhat less destructive to turnip, kale, collards, radish, mustard, and horseradish. It also does considerable damage to ornamental plants, such as nasturtium, mignonette, sweet alyssum, the spider plant (Cleome), and exceptionally to lettuce.

The butterflies sip the nectar of flowers of various kinds and may be seen at any time hovering over them. They are especially fond of the white blossoms of crucifers, and of the flowers of white aster, lavender, purple heliotrope, and thistle. Like other butterflies, this species is active by day, and is on the wing from early morning until near dusk. It is a comparatively slow, tireless flyer, being capable of extended flight for long distances. The butterflies sometimes congregate in immense swarms, as has occurred frequently when they have emigrated from the continent of Europe to England, and their occurrence in midocean has been recorded.

LIFE HISTORY.

The butterflies appear on warm sunny days as early as March, even in the Northern States, and thereafter may be seen flying until after several severe frosts in October. In the Gulf region they occur throughout the season.

Pairing and egg laying begin within a day or two after the adult issues from the chrysalis. The duration of the different stages naturally varies with temperature conditions, that of the egg period being from 4 to 8 days.

The caterpillar eats voraciously and grows rapidly, attaining maturity in from 10 to 14 days after hatching. It molts four times; hence there are five distinct instars or substages, the first molt taking place, in the warmest weather, in about 2 days from the time of hatching, the second stage lasting from 2 to 3 days, the third and fourth from 1 to 2 days each, and the fifth from 4 to 5 days. The duration of the chrysalis stage is from 7 to 12 days during the summer time, but the last chrysalides formed in the more northern States remain in suspense during the winter and develop the following spring.

The life cycle occupies periods varying between 22 days and 5 to 6 weeks. Even in New England this species is credited with being triple brooded, but in the District of Columbia and vicinity

there must be one or more additional generations, with a possibility of at least six in the extreme South. The first generation develops on wild plants.

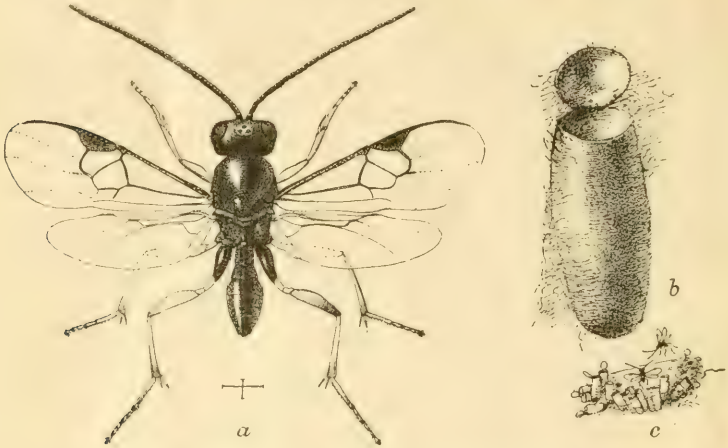

FIG. 7.—An ichneumon fly, *Apanteles glomeratus*, a valuable parasite of the common cabbage worm: *a*, Adult fly; *b*, cocoon; *c*, flies escaping from cocoons. *a*, *b*, Highly magnified; *c*, natural size. (Author's illustration.)

NATURAL ENEMIES.

Were it not for certain effective checks this species would be a still greater pest. The most important of its insect enemies are small parasites, all introductions from Europe. One of them, an ichneumon fly[1] (figs. 7, 8), was purposely imported in 1883 from England. During the autumn of 1904 this species held its host under complete control at Washington, D. C., killing every "worm" which came under the writer's observation. A larva which has been destroyed by this parasite is shown in figure 7, *b*, together with the parasite's cocoon. A minute chalcis fly[2] was present as a parasite of the beneficial ichneumon fly, but apparently did not destroy the effectiveness of the latter. Another chalcis fly[3] (fig. 9) which bears the same

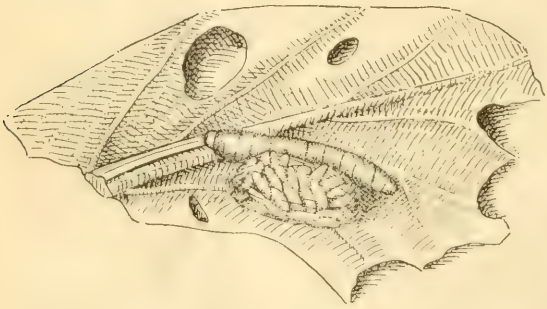

FIG. 8.—Parasitized cabbage worm, showing cocoon mass of ichneumon fly, *Apanteles glomeratus*, below. (Author's illustration.)

[1] *Apanteles glomeratus* L.; order Hymenoptera, family Braconidae.
[2] *Tetrastichus microgastri* Bouché.
[3] *Pteromalus puparum* L.

relation to the cabbage worm as does the ichneumon fly, and is therefore beneficial, was first noticed in this country in 1869, evidently having been imported with the host. The eggs of this species are deposited in the cabbage worm, which, while completing its transformation to pupa, dies, and the parasites issue from the latter.

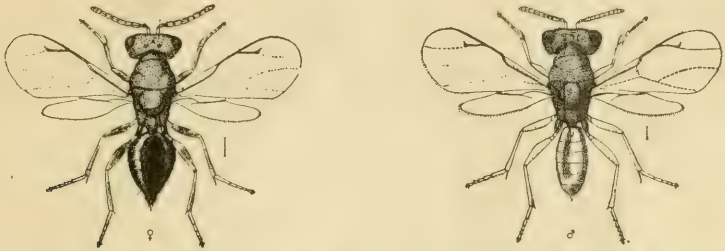

FIG. 9.—A chalcis fly, *Pteromalus puparum*, a parasite of the common cabbage worm: Female at left, male at right. Greatly enlarged. (Author's illustration.)

Wasps, particularly certain paper wasps[1] and related forms, are also of great service in reducing the numbers of this and other cabbage worms, appearing to prefer them to other prey.

The small, evil-smelling ambush-bug[2] (fig. 10) secretes itself in flowers, such as the thistle and goldenrod, and destroys numbers of butterflies, capturing them and sucking out their body fluids.

FIG. 10.—An ambush-bug, *Phymata wolffii*, which preys on butterflies of the common cabbage worm: *a*, View from above; *b*, view from side; *c*, front leg; *d*, beak. *a*, *b*, Enlarged; *c*, *d*, more enlarged. (Riley.)

Numerous other enemies[3] attack this cabbage worm, and it is sometimes subject to a contagious bacterial disease[4] similar to that of the cabbage looper. It is, however, less susceptible to this malady; although in some seasons, for example, in 1916 in southern California, great numbers are destroyed by it.

Birds which are known to feed upon cabbage worms are the chipping sparrow, English sparrow, and house wren. It is certain, however, that other species eat them, and in one case it was found that during the winter the number of pupæ of the cabbage butterflies was reduced more than 90 per cent by birds feeding upon them.

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[1] *Polistes metricus* Say, *pallipes* Lepel., *et al.*

[2] *Phymata wolffii* Stal.

[3] Among other predacious enemies observed in this country are the wheel bug (*Arilus cristatus* L.) and the armed soldier-bug (*Podisus maculiventris* Say). The cabbage worm is also parasitized by the tachina flies *Exorista vulgaris* Fall and *Frontina archippivora* Will., as well as by *Sarcophaga* (*Boettcheria*) *latisterna* Parker. About 10 additional European parasites are listed.

[4] *Micrococcus pieridis* Burrill.

METHODS OF CONTROL.

The imported cabbage worm is not difficult to control, and it should be borne in mind that most other "worms" will be controlled by the same methods, and that other cabbage pests are more often present than not.

ARSENICALS.

Repeated experiments have shown that the best remedy is one of the arsenicals; and that arsenate of lead and Paris green are preferable to others in common use. If Paris green is used it may be applied either wet or dry, preferably, however, as a spray, at the rate of 1 pound to 50 gallons of water. The plants should be free from insect attack when they are set out, and should be sprayed a few days later to make sure that the poison reaches the young caterpillars before they have burrowed far into the heads. Other applications should follow as inspection of plants shows that they are necessary. These applications of arsenicals can be made with absolute safety until the heads are nearly formed, and, for that matter, even later, as the poison disappears from plants almost completely within two to three weeks after application, and even earlier in event of repeated or heavy rainfall. After the removal of the outer leaves, in preparation of the cabbages for market, and after other leaves have been picked off, as is done before the cabbages are cooked or cut up for salad, there is usually very little, if any, of the arsenic left.

HARMLESSNESS OF ARSENICALS WHEN PROPERLY APPLIED.

Chemical analysis has shown that cabbage which has been sprayed or dusted with an arsenical as prescribed, and prepared for cooking in the usual manner a week later, has not even a trace of the arsenic remaining. The use of arsenicals against cabbage worms is almost universal in the United States, although growers are sometimes loath to acknowledge the fact for fear of the loss of customers who are not fully acquainted with the harmlessness of the remedy. There are no authentic recorded instances known to the writer of poisoning from the consumption of cabbage treated with an arsenical. It has been proved that 28 cabbage heads, dusted in the ordinary way with Paris green, would have to be eaten by an adult human at one meal before poisonous effects could be produced. The experience of a Virginia market gardener who dusted his cabbage with Paris green and flour, omitting to inform his family of the fact, should be cited. A day or two later he ate heartily of this cabbage, as did others, and afterwards was questioned by his wife as to the peculiar powdery substance on the heads. Although poisoning was anticipated, no ill results followed.

ARSENATE OF LEAD.

As a result of the abnormal conditions incident to the European war, there is a scarcity of Paris green, which has naturally increased the cost. Arsenate of lead, however, which has been rapidly superseding Paris green and other arsenicals as an insecticide, has not increased proportionately in price, and for many reasons is preferable.

It has the advantage of being less harmful to growing plants and adheres better to the foliage, is less apt to burn the leaves of delicate plants, and is less troublesome to prepare. It serves the same purpose as Paris green and is applied in the same manner. It is sold both in paste and in dry powder form. Two pounds of dry lead arsenate to 50 gallons of water or Bordeaux mixture will make a solution of sufficient strength to destroy cabbage worms and similar insects. It may, indeed, be used as strong as 1 pound to 10 gallons of water on hardy plants without injury, but this is inadvisable because of the increased cost, the danger of scorching young plants, and the fact that, thus used, it is no more effective than the prescribed dose. The paste form must be used at double strength, or 4 pounds to 50 gallons of water. The number of sprayings to be applied depends on local and seasonal conditions. Sometimes a single spraying at the proper time will suffice, but usually two or three applications are necessary for cabbage worms which have more than one generation. The adhesiveness of the spray material is promoted by the addition of about the same amount by weight of resin-fishoil soap as of the arsenical used.

Arsenate of lead as a spray is valuable in that it leaves, on drying, a white coating on the plants, so that after spraying it can be determined readily which plants have been treated and which have not been reached.

Extensive experiments have proved that, for economy and efficiency, the best form of spraying machinery should be used. In regard to nozzles the "Vermorel," "cyclone," and "mistry" types are most effective as well as the most economical. When the arsenical is forced through a nozzle of this type the spray is mist-like in appearance and adheres to the foliage instead of forming small drops which quickly roll off the smooth leaves of cabbage plants. The best sprayer is the compressed-air type, constructed for use both by hand and by machinery, the latter to be driven by horsepower.

POISONED-BRAN MASH.

A mixture of bran with Paris green, the standard remedy for cutworms and grasshoppers, is, according to the testimony of some who have used it, successful against "cabbage worms," and should be tested against the imported cabbage worm. Any arsenical can be

employed in the preparation of this mixture. It is best to mix the bran with the poison and sugar before adding the water. The proportions are 2 or 3 ounces of sugar or other sweetening, a teaspoonful of Paris green, and about 1 pound of bran, to a gallon of water; so as to make, when stirred, a mixture that will easily run through the fingers. In its application it is merely sprinkled, either wet or dry, over the affected plants.

THE HOT-WATER REMEDY.

As long ago as 1883, water at a temperature of about 130° F. was advised as a remedy for this cabbage "worm." It does practically no harm to the plants and kills all insects with which it comes in contact. It is scarcely applicable to large fields, however, on account of the difficulty of maintaining the proper temperature.

CONTACT POISONS.

Kerosene emulsion is not as effective as the arsenicals, because in its application it is necessary for the spray to come into direct contact with the larvæ or "worms" in order to kill them.

When strong soap solutions are used on ornamental plants infested by aphides or plant-lice and this species is also at work, such insects as are actually touched will be killed. Where the plants affected are attacked by thrips and other minute insects, and such contact poisons as nicotine sulphate are employed, these will also kill cabbage worms, but none of the poisons of this nature are standards for the chewing insects like the cabbage worms, and are not recommended except in the case of the occurrence of sucking insects on the same plants. A combination spray of an arsenical mixed with nicotine sulphate, kerosene emulsion, or soap is sometimes used with good effect to kill both aphides, or thrips, and cabbage worms.

PYRETHRUM.

Pyrethrum insect powder is not so useful as an arsenical. Of its effectiveness, Dr. James Fletcher, late entomologist of the Dominion of Canada, wrote that "diluted with four times its weight of common flour and then kept tightly closed for 24 hours (before use), it leaves nothing to be desired, and thousands of dollars are saved yearly to small growers, who most need assistance." Pyrethrum is rather costly, varies as to purity, and is said to discolor the leaves, but it has the advantage of being nonpoisonous to human beings and domestic animals. If used too sparingly a portion of the caterpillars are merely numbed and eventually recover. Younger caterpillars are more susceptible. It can not be recommended for use on large areas.

HAND METHODS.

For the kitchen garden, hand picking is sometimes practiced, especially when plants are first set out. It is laborious, although effective if the work is carefully conducted.

CLEAN FARMING AND TRAP CROPS.

If cooperation in clean methods of farming and in the use of arsenicals could be secured by any possibility, much of the loss due to the ravages of this pest might be averted. The practice of leaving cabbage stalks in the field after the main crop has been harvested is reprehensible. All remnants should be gathered and destroyed, with the exception of a few left at regular intervals through a field as lures to induce the female butterflies to deposit their eggs upon them. Such stalks, being useless, should, where feasible, be poisoned freely with arsenicals so that the last generation will have no place to develop in the fields.

UTILIZATION OF NATURAL ENEMIES.

It is matter of common observation, frequently recorded, that two parasitic enemies of this species do excellent service in reducing the numbers of their host, viz, the cabbage-worm chalcis fly [1] and an ichneumon fly.[2] (See pp. 8–9.) The former issues from the chrysalides through minute holes in the dry outer skins. The latter issues from the caterpillars and forms masses of yellow cocoons. As soon as these cocoons are seen, all caterpillars that can be collected should be gathered carefully with portions of the leaves to which they are attached and transferred to barrels or large boxes, which should be covered with wire netting of a mesh which will permit the parasites to emerge but will prevent the butterflies from escaping. An ordinary screen mesh of 12 to the inch or coarse mosquito netting will answer this purpose. In addition, a few holes should be bored into the bottom of the barrel or box used for this purpose, small enough to prevent the caterpillars from escaping. This will permit rain water to drain off which might otherwise drown the insects.

SUMMARY.

The imported cabbage worm is a velvety green caterpillar measuring about an inch and a fourth when full grown. It is the larva or young of a white butterfly. It begins work soon after young plants are set out, and in the case of cabbage riddles the outer leaves and bores into the heads. As a result entire crops are often lost.

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[1] *Pteromalus puparum.* [2] *Apanteles glomeratus.*

It was introduced from Europe and has been known in the United States since 1865. It has become a most serious drawback to the cultivation of cabbage, cauliflower, turnip, and related crops in this country.

The first generation is produced on wild cruciferous plants, and the second attacks crop plants. It is capable in the warmest weather of developing from egg to adult or butterfly in 22 days. Even in its northernmost range it is triple-brooded, and southward there may be as many as six distinct generations.

Two natural enemies contribute considerably to the decrease of this species, otherwise it would be a pest of still greater severity.

The best remedies are the arsenicals, of which arsenate of lead and Paris green are the most efficient; the former, being cheaper at the present time, is recommended at the rate of 2 pounds in powder form or 4 pounds in paste form to 50 gallons of water. Adhesiveness is enhanced by the addition of about the same amount by weight of crude resin soap or resin-fishoil soap.

The best form of spraying machinery should be used, with special attention to nozzles in order to secure a mist-like spray.

The arsenicals are harmless when properly applied as directed.

In addition to the persistent use of arsenicals, clean farming should be pursued in cooperation with neighboring cabbage growers to obtain the best results.

It is advisable to encourage the parasites above-mentioned according to the directions given.

Finally, cooperation in the use of arsenate of lead as a spray and in maintaining clean farming and other methods is highly desirable in all communities. If this could be practiced on an experimental scale under proper supervision the results would soon be apparent. It must be kept up year after year, however, owing to the constant migration and invasion of this cabbage worm from other sources.

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