Insects

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Contribution from the Office of Experiment Stations, A. C. True, Director, and the Bureau of Entomology, L. O. Howard, Chief.

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COLLECTION AND PRESERVATION OF INSECTS AND OTHER MATERIAL FOR USE IN THE STUDY OF AGRICULTURE.[1]

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INTRODUCTION.

This bulletin suggests methods of collecting, preparing, mounting, and preserving insect specimens and other illustrative materials of various sorts which can be used by teachers of agriculture,[2] particularly those teachers who have not had special training along agricultural lines and who will therefore doubtless welcome specific information as to how to prepare materials needed for illustration and experimental use in the classroom.

WHAT MATERIALS SHOULD BE COLLECTED.

The nature of the material which the teacher should aim to collect will depend, of course, upon the character of the school and the class of work which is taken up, as well as upon the locality, the funds available, and the time which can be devoted to the work.

In general, the illustrative materials with which every school should be provided may be grouped into two classes, according to the uses to which they are to be put: (1) Museum specimens and samples which are to be kept permanently for reference, display, and strictly illustrative purposes only; and (2) working collections, which may be used for display and illustration, but the chief purpose of which is to supply the students with materials for class study and experimental use. For instructional purposes the latter is by far the more valuable, but a permanent collection of insect specimens and samples of various other materials may be very useful to any school, provided, of course, the specimens are accurately labeled and so preserved and mounted that they are readily available for examination. It is with

[1] This bulletin is intended for the use of teachers in rural schools throughout the country.

[2] Methods of collecting plant materials for this purpose are described in Farmers' Bulletin 586, which can be had on application to the United States Department of Agriculture, Washington, D. C.

the solution of this problem that it is intended to deal particularly in this bulletin.

Materials for class use should, as far as possible, be fresh and in the natural state rather than in mounted form, and will therefore generally be collected just prior to the time they are wanted and put away only temporarily. No great degree of care or skill will, in general, be necessary to do this, but the preparation of materials for the permanent collection in a school museum often requires considerable technical knowledge and ingenuity in preparing and preserving the specimens and preparing convenient receptacles in which to keep them. This is particularly true where the means at hand are limited and the resourcefulness of the teacher must be relied upon to produce inexpensive methods and devices of home manufacture.

SOURCES OF THE MATERIAL.

In recent years many commercial houses, educational institutions, and Government bureaus have distributed collections of specimens and samples of various sorts to schools. Such collections are of great value, undoubtedly, and there is no objection whatsoever to schools securing materials from such sources whenever possible, so long as they do not rely upon these sources for all their illustrative material. It is, however, a much better policy to attempt, as far as possible, to have the pupils collect and prepare their own materials from original local sources, because of the possibilities for educative work involved in the process of gathering the various specimens.

Every community affords opportunities for collecting insects and other materials of vital importance in the study of agriculture, and the work of gathering these specimens will afford definite tasks upon which to center the interest of numerous field trips, so that the danger of aimless wandering, which so frequently makes this method of instruction devoid of practical results, may be minimized. The instructor who takes his class out into the field or orchard with the definite purpose to collect insects, for example, has the very best possible opportunity at the same time to teach, not only identification of the local insect species, but also useful facts as to their economic importance.

GENERAL SUGGESTIONS FOR FIELD WORK.

It is important that the pupils should be provided with notebooks and pencils for making complete and accurate records which should be kept for each specimen collected, in order to supply the data necessary for the proper labeling of the mounted specimen.

All work of this sort should be constructive and never destructive. Wanton destruction of insects, except those which are injurious to man or his crops, should be denounced and the young encouraged to watch the living insects and learn all they can of their habits.

SUGGESTIONS CONCERNING THE ARRANGEMENT OF MATERIALS.

When insects or other materials are collected for ordinary purposes of study and reference, it will generally suffice to arrange the specimens in their logical order, according to their scientific classifications. When, however, it is intended to prepare a set of specimens for an educational display, very interesting and attractive groups can be arranged to show strikingly the agricultural relationships of the particular insects in question. For example, a display might be centered about some farm insect pest which would show the insect in various stages of its development; specimens of the plants upon which it feeds, showing the injury it does to these plants; specimens of other insects which are hostile to it; and pictures of birds which prey upon it. Exhibits such as this take time to prepare, but they will prove enough more attractive than an ordinary collection to warrant the extra labor and thought involved in their preparation.

COLLECTION OF INSECTS.

WHAT INSECTS TO COLLECT.

When proper methods are followed, the collection of insect specimens can be made the basis of a great deal of useful instruction in connection with the subject of agriculture. There are numerous species that are really beneficial to the farmer, and these should, of course, be studied, but one generally thinks of insects as injurious to agricultural interests because of the great number of species that are annoying about the household or injurious to farm animals or farm crops. These insect pests should form the basis of most of the work of the class in agriculture rather than the butterflies and harmless insects of purely entomological interest, or even the beneficial species.

It should be the aim of the student of agriculture to collect and become familar with not only the adult forms of these insects, but also their larvæ and pupæ, since it is often in the larval stage that these pests are most injurious. Further, the pupil should become familiar with the life histories of the various species, since this will often furnish the key to the proper methods of combating the pests.

EQUIPMENT FOR INSECT-COLLECTING TRIPS.

The articles necessary for collecting insects are not very numerous and such as are most needed can be made by the pupils or the teacher with very little expense or trouble. The necessary equipment for an insect-collecting excursion should include collecting nets, killing bottles, a box containing some vials partly filled with alcohol in which to place specimens of larvæ and pupæ, a trowel for digging specimens out of the earth, a small hatchet for breaking open rotten stumps, some sheets of newspaper or other soft paper, size about

3 by 5 inches, for making envelopes in which to put delicate specimens of butterflies or moths, a small bottle of chloroform or gasoline, and a small hand satchel, haversack, or botanical specimen case, with a few small pasteboard boxes, such as pill boxes, in which to put insects after taking them out of the killing bottle. A small pair of forceps or tweezers will also be found convenient for handling some of the specimens, and a pocket lens will be a desirable aid for the study of the specimens in the field.

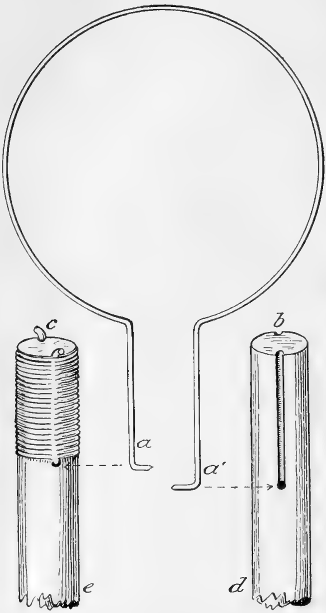

FIG. 1.—Homemade ring and handle: *a a'*, ring; *b*, stick showing grooves ending in hole; *c*, wire inserted in groove and hole, and wrapped with twine.

FIG. 2.—Net and killing bottle for insect collecting.

THE INSECT NET.

Anyone can make a satisfactory insect net (figs. 1 and 2). All that is necessary is a bag of thin material, a ring to support the bag, and a handle to be fastened to the ring. Bags are made of various materials. For beating through weeds and bushes it is best to have a bag of stout material, as twilled muslin or light duck cloth. For capturing butterflies and most flying insects a light net of cheesecloth or mosquito netting does very well for the beginner. The material should be such as not to stiffen or kink by use. Expert collectors often use bags of silk.

As a rule the length of the bag should be twice its diameter. The common size is 1 foot in diameter and 2 feet long. The bag is best if made to taper a little at the bottom, and the edges should be double hemmed (French seamed), so as to leave no free edge that may fray out. If the bag is of light material, it should be sewed to a band of stout muslin at the top. This band should be double and open at each end for the insertion of the ring, or else sewed on the ring. The ring may be of any heavy wire about the size of telephone wire. Bought rings usually have two or three joints to allow for folding, but although this is convenient for packing it is not important. The wire should be several inches longer than necessary to form the ring, the extra length bent at right angles, and the last half inch again bent at right angles. The stick or handle, about 2 or 2½ feet long, should be stout but not too heavy. A groove almost the size of the wire should be cut on each side near the end of the stick, ending in a hole; then the bent ends of the ring should be inserted in the hole and all wound tightly with twine, or a metal jacket slid over the ends to hold them in place. A longer and lighter handle of bamboo is better for collecting butterflies and dragon flies. It will be necessary to leave a few inches near the upper end of the bag unsewed in order that the ring can be inserted into the band. This part can be laced up with a string and the ends of the string tied to the handle. This will keep the net from slipping around on the ring.

For catching small insects a midget net of 5 or 7 inches in diameter is useful and can be made on the same plan as the larger one. The ends of the wire of the net can be inserted in a spool and a stick for the handle wedged in between the ends of the wire. This net is very handy for collecting insects from flowers and, in fact, for general collecting. The material for the bag of the midget net should be very light; white China silk lining is a good material.

For collecting aquatic insects a more open mesh or sieve net can be attached to an iron frame which is straight on one side and bowed up on the other. With cords attached to each side this may be thrown into the water and, after sinking to the bottom, drawn to shore. Dredging among the weedy or sedgy parts of a pond is especially productive of insects.

Many insects are attracted to lights, and a strong lamp with a reflector to throw the light upon a white sheet will serve to attract many insects, particularly on sultry nights. A mixture of sugar or molasses and decaying apples smeared on trees in the woods will often attract moths at night. A bull's-eye lantern is useful in examining these patches in the evening.

Many insects that occur on the trunks of trees may be captured easily by putting a small cyanid vial over them; thus one avoids handling the specimens. For collecting insects from the branches and leaves of trees, an inverted umbrella is the most useful implement. Hold it at arms length under the tree and jar the limb with a heavy stick. A sudden shock will dislodge many beetles and other insects that one would not have noticed upon the tree.

Cans or bottles sunk in the ground so that the top is even with the top of the soil and baited with meat, a dead mouse, rotten apples, etc., will be visited by various insects. Boards or pieces of bark left on the ground near the edges of woods and meadows will serve as shelters for a variety of insects, and if visited occasionally one will find many interesting specimens. Always turn back stones, logs, or boards after examining them so that they will continue to attract insects.

FIG. 3.—Poison bottles.

Many insects occur among dead leaves and moss. These may be sifted out on a white paper or cloth by the use of a sieve similar to an ash sieve but with a finer mesh. On collecting trips one should take along some empty pill boxes or larger tin boxes for caterpillars and other larvæ.

One must always be careful in taking insects from a net not to crush them nor rub the scales from the wings of butterflies and moths. Always handle specimens as little as possible.

THE KILLING BOTTLE.

After the insect is caught it is necessary to kill it with as little pain to the creature as possible and without damaging the specimen. Insects are so different from human beings and their sensations appreciated through much less perfect organs and their brains of such a very inferior nature that it is improbable they feel much pain through death. Many insects can have their legs and other parts broken from them without incapacitating them in any way, and many kinds have parasites living within them and feeding on their internal organs without their exhibiting any sign of pain; so there is no need to feel that we are harming helpless creatures by collecting insects. Still, for the sake of the effect on the collector, it is not well to gather nor destroy more than is necessary for this purpose.

Insects may be killed by a vapor of chloroform, ether, sulphur smoke, etc., but by far the best way is by the vapor of potassium cyanid. This potassium cyanid is a hard white substance which can be purchased at drug stores. It is a deadly poison. The cyanid may be broken into small lumps, put in a bottle, covered with a little dry plaster of Paris, and then with a layer of plaster of Paris mixed with water so as to cover the cyanid about one-quarter of an inch. The bottle should be left open an hour or so to dry, and then kept tightly corked so that the fumes of the cyanid will be strong enough to kill an insect in a few moments (fig. 3). A label with the word "Poison" should be pasted upon it. It is well to place some crumpled strips of soft paper in the bottle to absorb any moisture and to prevent the insects from shaking against each other. A well-made poison bottle will last several years. The bottle should be of thick

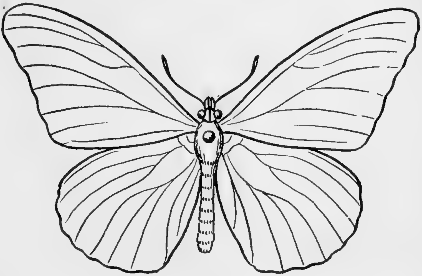

FIG. 4.—Method of pinning butterflies.

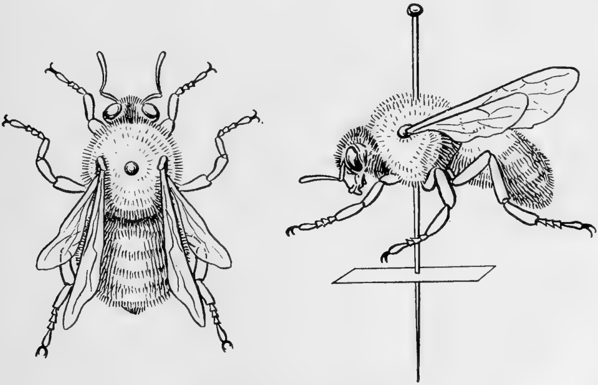

FIG. 5.—Method of pinning bees.

glass, with a wide mouth and a tight fitting cork that does not set down too far for convenient handling. Some make a poison bottle by wrapping bits of cyanid in soft paper and covering all with blotting

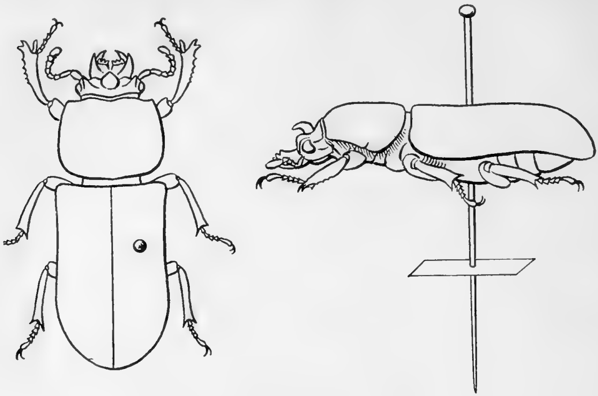

FIG. 6.—Method of pinning large beetles.

paper wadded down in the bottom of the bottle. This does very well for a small bottle but one should be very careful to have bottles of thick glass. Potassium cyanid is a deadly poison and the greatest amount of care must be exercised in handling it and if any is left over or a bottle broken it should be buried deeply in the ground. Poison bottles should not be left open in the room nor left where small children can get at them, and older children should be impressed with the possible danger. It is best that the teacher should have all the bottles returned after each collecting trip.

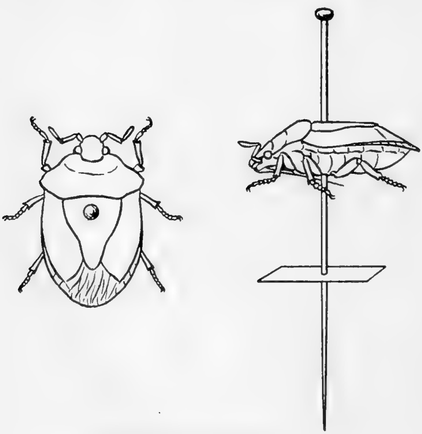

FIG. 7.—Method of pinning bugs.

Specimens should not remain in the poison bottle more than a day or two. In fact, insects with yellow markings should not be left in over night as the yellow will turn to red.

Most entomologists use many small cyanid vials or bottles of only about ½ to 1 inch diameter and 2 to 4 inches long. By taking several of these along on a trip, it is possible to keep insects of different sizes and kinds separate, for small flies are apt to get broken if put into the same bottle with large, heavy beetles. It is best not to put moths and butterflies in a bottle with other insects, as the latter are apt to become covered by loose scales from the moths or butterflies.

There is much less danger in handling insects than is popularly believed, since but few species are either poisonous or likely to injure the collector by biting or stinging. Insects like the wasps and bees will sting, of course, and a few of the larger beetles may pinch or bite, but these are generally well known and there are but comparatively few insects whose bites are poisonous.

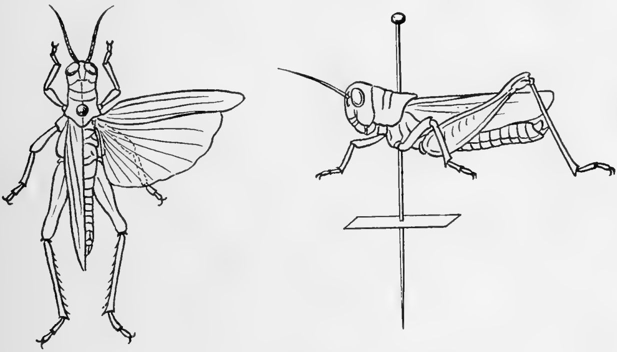

FIG. 8.—Method of pinning grasshoppers.

PINNING INSECTS.

Common pins are too large for most insects, and so entomologists use a longer and more slender pin. These pins can be purchased from dealers in natural-history supplies for a dollar or less per thousand. They are made bright, black, or japanned. The black pins cost a little more, but are much better for most insects, since the specimens will not verdigris. Verdigris is a poisonous green substance that may develop on an insect at the point where a bright pin goes through the specimen; it injures the specimen and eventually may destroy the pin. Some insects never verdigris, but those insects which feed on woody substances and many that live in the water are very apt to verdigris if pinned with a bright pin. The pins come in sizes according to number. No. 2 is a very good size for most insects, No. 1 for small insects, and No. 3 or 4 for the large ones. For use in school collections No. 2 will be the best size.

Most insects, like butterflies, moths, bees, and flies, should be pinned through the middle of the thorax (that part of the body to which the wings are attached) (figs. 4 and 5), but beetles should be pinned near the upper end of the right wing-cover (fig. 6), and true bugs through the scutellum (a triangular piece between the bases of the wings) (fig. 7). Grasshoppers are often pinned through the tip of the prothorax, a little in front of the base of the wings (fig. 8). The insect should be pushed fully two-thirds of the way up on the pin, and the collection will make a much better appearance if all the specimens are of an even height. Those specimens too small for a pin should be mounted on micropins (short pieces of slender wire having a pointed end) or glued on the ends of slender triangular pieces of cardboard called points (fig. 9). When the micropin is used, it is put into one end of a small oblong piece of cork and a large pin put through the other end of the cork. The points (about one-third inch long) may be cut from any fairly stiff cardboard. A pin should be inserted through the broad end, a little glue or shellac put on the point, and the insect laid upon it with the back outward, and its head away from the preparator when the point is to the left of the pin. Small beetles and true bugs are glued with the back up rather than on the side. It is very important that all specimens be correctly identified before they are permanently assigned to a place in the school collection. Entomologists usually have little two-lined labels printed in diamond type, giving the locality where the specimen was captured and a blank space for writing in the date of capture. These labels are put well up on the pin, a little below the insect, so as not to interfere with the legs. For school purposes labels may be written with a fine pen, care being taken to write them in a small and neat hand. Insects found eating plants should have a little label, giving the name of the plant, and the entomologist also usually places on a label the name of the collector of the specimen. Children should be impressed with the idea that carefulness in these little details counts in the value and usefulness of a collection. Additional information and aid along this line may frequently be had from the State agricultural college or experiment station or from officials of the State department of agriculture.

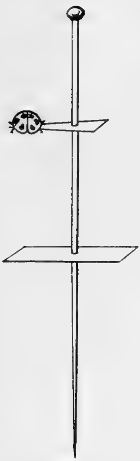

FIG. 9.—Method of mounting small insects.

SPREADING INSECTS.

Insects should be prepared and mounted as soon as possible after they are collected, for if they are left for any length of time the wings and legs will become stiff and easily broken, and it will be impossible to spread the wings as will often be desirable in order to give the specimen a lifelike and attractive appearance. If it should be impossible to mount the specimens until they have become rigid, they can be relaxed by placing them for a time on a piece of paper in a box partly filled with moist sand. It will be well to put a few drops of carbolic acid on the sand in order to prevent molding. After being left in this way for a few days the insects will generally be sufficiently relaxed to make it possible to mount them without great difficulty.

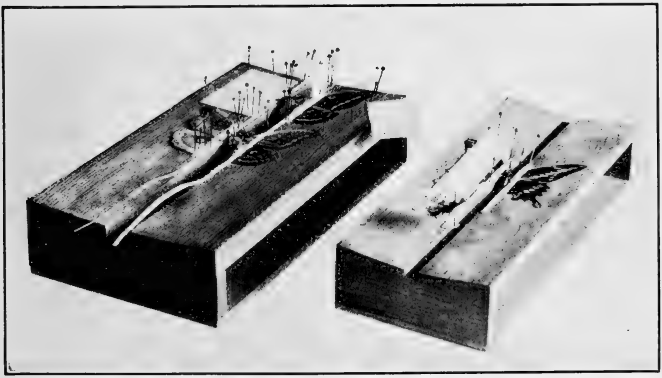

FIG. 10.—Spreading boards.

Butterflies and moths, dragon flies, and similar insects should have their wings spread out at right angles to the body. This is done by the use of a spreading board such as is shown in figure 10. Two strips of some soft wood, such as linden, white pine, or white wood, are fastened on low cleats resting on a bottom board. A strip of cork is fastened to the underside of the strips to cover the groove between them. The pin is pushed through the cork until the body of the insect rests upon it, and the wings are then stretched out on the boards by pulling them forward with a pin inserted near the front margin. They should be pulled out far enough so that the hind margin of the front wings will form a straight line. Then the wings should be held in place by strips of paper pinned down tightly at each end. The specimen should remain on the spreading board for at least a week, so that when removed the wings will stay spread and not relax to the normal condition. Care should be taken in placing the strips across the wings, so as not to rub the scales from the wings of butterflies and moths. With grasshoppers it has been customary to spread the wings of one side only.

BOXES.

If it is desired to keep the insects for several years, it is necessary to put them in a tight, dry, and dark box—tight to exclude other insects which would eat them, dry to prevent mold, and dark to preserve their colors.

FIG. 11.—Covered box for insect specimens.

There are two sizes of boxes commonly used by collectors. One is a box about 9 by 12 inches with a hinged top (fig. 11). These often stand on edge on a shelf. The other is a larger box or drawer about 15 by 18 inches with a removable glass top. These drawers are arranged to slide into a cabinet. Cabinets, with three or more drawers, that will be excellent for school collections, can be purchased from dealers. For the purpose of temporary study insects may be kept in any style of box with a cover. Cigar boxes will do for a time (fig. 12). The bottom of the box should be lined with some soft material, such as cork, peat, well-dried corn pith, or corrugated paper, and covered with soft paper. To prevent other insects from coming in and eating the specimens, a pinch of flake naphthalene or a naphthalene cone should be placed in each box. Within the box the specimens should be arranged, each kind by itself in a row. A label with the name of the insect can be placed behind the row of each species, or attached to the first specimen in the row.

In recent years a new mount has been developed for exhibiting insects and their life histories and it is most excellent for use in schools. It consists of a pasteboard box about one-half inch thick, the top having a glass cover (fig. 13). This box is filled, not too tightly, with cotton. The insect is spread out on the cotton, the top pressed down and held by pins. These mounts can be purchased from dealers

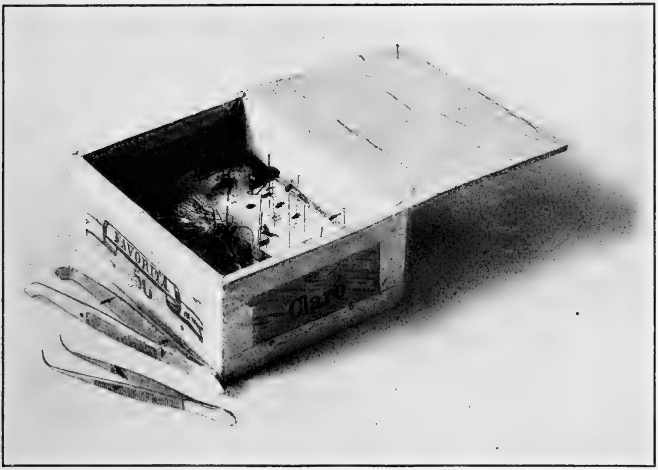

FIG. 12.—Cigar box for insects.

and are very useful for passing around in a class, or may be hung as pictures on the walls of the schoolroom. The eggs, caterpillar, chrysalis, and the adult, as well as a part of the plant eaten, can all be put in the same mount and thus exhibit the life history of the insect. To fumigate the specimens perhaps the best way is to place in the box with the specimens a small tin lid or other small shallow vessel and put into it about a tablespoonful of formaldehyde or of carbon bisulphid. The latter substance is inflammable and should not be handled near a fire. The fumes from both these substances are very annoying and disagreeable, hence it will be advisable to do this fumigating out of doors, or in an outbuilding, never in the schoolroom.

The specimens illustrating the life histories of insects will not be complete unless the larvæ are preserved, and it is often in this form that the creature is most injurious to crops. Furthermore, there are some soft-bodied insects, like the spiders, which can not be preserved dry. These specimens must, therefore, be preserved in fluids. A good fluid for this purpose can be made by mixing 10 parts of formalin (40 per cent formaldehyde), 100 parts 95 per cent alcohol, and 100 parts distilled or boiled water.

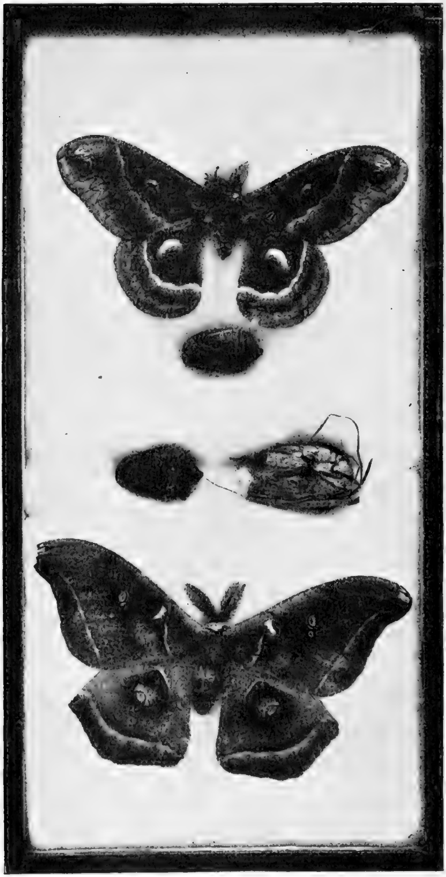

FIG. 13.—Series of specimens illustrating life history of a moth.

KEEPING LIVE INSECTS—BREEDING CAGES.

One of the most interesting phases of insect study is the rearing of insects. The simplest way is to collect the cocoons attached to various trees in the autumn, and the fine moths, red, brown, or pea-green, will appear the following spring. It is more instructive, however, to collect the larvæ or caterpillars and place them in a box where they can be supplied each day with the proper kind of leaves for food. By this means one can watch the caterpillars change their skins while they grow, and also note the change from the caterpillar to the pupa or chrysalis. Any box with a top of netting to prevent the caterpillars from getting out will be suitable. By putting moist sand in the bottom of the box, the food will keep fresh a longer time.

A very convenient and useful breeding cage is made by putting a lamp chimney in a flower pot (fig. 14), the top of the chimney covered with a piece of gauze or mosquito netting. With a saucer outside containing water the sand or earth in the pot can be kept moist so that twigs of the food plant will remain fresh for some time.

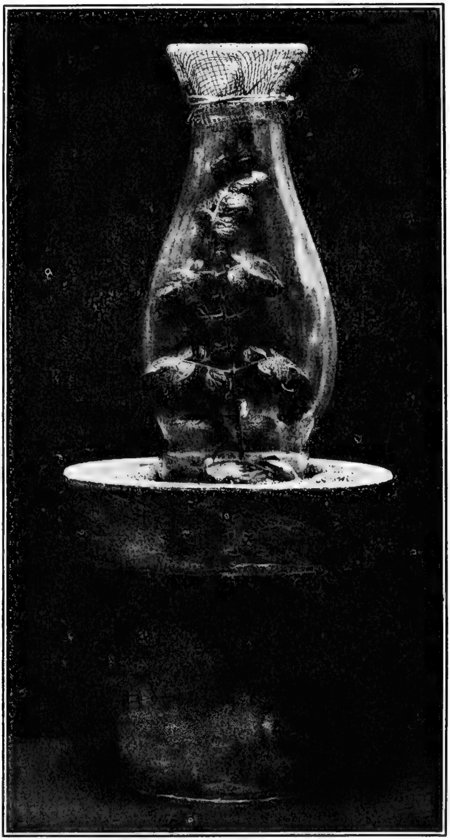

FIG. 14.—A simple breeding cage for insects.

It is interesting to keep ants in an artificial nest. A simple one may be made by taking a piece of board at least $1\frac{1}{2}$ inches thick and about 12 inches square and making a channel 1 inch wide and $\frac{3}{4}$ of an inch deep all around the near edge. This channel should be nearly filled with water. On the center of the board put two pieces of glass about 8 inches square and between them a thin layer of soil or comminuted wood. Cover the top glass with a blackened board or tin. Ants placed between the plates of glass will excavate tunnels and if fed may be kept a long time.

If galls of insects are collected in the fall or winter many specimens will issue in the spring. Twigs of oak and other trees blown off in the fall or winter may contain beetles and if placed in a room the insects will issue and fly to the windows. In rearing moths or other insects one sometimes finds that instead of the expected specimen there appears a quite different insect. This is usually an Ichneumon or Tachina fly. The young of these live parasitically in the caterpillar and destroy it. These parasites should be saved and when possible the name of their insect host should be put on the label.

More extended directions covering special kinds of collecting can be obtained by applying to the United States National Museum, Washington, D. C.

COLLECTION OF ROCK AND SOIL SPECIMENS.

While an exhaustive knowledge of geology is not essential to the study or practice of agriculture, it is important that the student of agriculture should be familiar with the more important types of soils and the processes by which these soils are evolved from mineral or vegetable sources. For this reason the pupils should collect and study specimens of the more important rocks, such as granite, sandstone, and limestone, from which various types of soils are formed by decomposition. These rock specimens should be chipped with a hammer to a convenient size and shape for handling and storing, say into rectangular blocks about 2½ by 4 inches in area and 1 to 1¼ inches thick at the center. Each specimen should bear a catalogue number or a label indicating the kind of rock and the place of collection. The label itself may be pasted on a smooth surface of the rock or the catalogue number may be painted on it and the description written in a book kept for that purpose. The specimens may be kept in boxes or in trays on cabinet shelves in the schoolroom.

Besides these specimens the pupils should collect, where possible, rock specimens showing evidences of the natural processes by which the rocks are decomposed to form soil. Thus, rocks bearing evidence of weathering, of glacial scratching, or the wearing effect of running water, should be collected and properly described.

To show the process of soil formation by the decay of vegetable matter, go into the forest where there is a deep layer of leaf litter and take up a section of the soil cover down to the mineral soil. Place this in a glass jar, preserving as nearly as possible the positions of the various strata—on the bottom the soft black mold or humus, above this the half-decomposed vegetable matter, and on top the fresh layer of leaves and twigs—thus showing the various stages in the formation of humus.

Collect specimens of all the types of soils found in the vicinity and classify them as sand, clay, silt, loam, or humus. Keep these in glass jars so that their textures and colors may be examined readily. Each jar should, of course, bear a proper label, indicating the type of soil it contains and the place where the specimen was obtained.

OTHER ILLUSTRATIVE MATERIALS.

COMMERCIAL FERTILIZERS.

It will be a good idea for the school to secure samples of commercial fertilizers sold on the local market, keeping these in small bottles, labeled with the name under which the product is sold, and, if possible, its composition.

MANUFACTURED PRODUCTS.

By way of illustrating the commercial importance of farm products interesting collections can be prepared to show the various ways in which these products are utilized in trade. Thus, a series of articles might be prepared to show the products which may be manufactured from corn, such as breakfast foods, corn sirup, cornstarch, corn oil corn rubber, commercial foods for live stock, paper made from cornstalks, cellulose made from the pith of the stalks, and numerous other articles. In like manner, the uses of other farm products, such as cotton, oats, wheat, and others may be illustrated.

LANTERN SLIDES AND PICTURES.

Nearly every well-equipped school nowadays has facilities for using lantern slides to illustrate special lessons on various topics. No subject presents greater possibilities for the use of slides than agriculture. Slides which will be of interest to agricultural students can be purchased from commercial firms or from other sources, or, if the school can not afford to own a set of slides, there are always opportunities to borrow or rent special sets for temporary use.[1]

Every school in which agriculture is taught ought to own a collection of pictures to illustrate the work. Photographic prints are, of course, the most desirable; but when these can not be obtained, half-tone cuts, or even line drawings taken from the pages of agricultural papers and from similar sources, can be used to advantage. In many schools either the teacher or some of the pupils will have cameras, and thus original photographs may be obtained for the collection. It is suggested that these pictures be mounted on good quality gray cardboard mounts of uniform size and filed upright, under convenient classifications indicated by guide cards, in a drawer or letter file. It is not advisable to paste pictures of this sort into a bound scrapbook, since in this form they can not be so readily used by the class.

Some of the kinds of pictures which should be collected are the following: Types of the various breeds of farm animals; views of good farm buildings and well-arranged grounds; good types of farm products, such as well-formed ears of corn; views illustrating the

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[1] Lantern slides on agriculture and forestry can be purchased or borrowed to a limited extent for educational purposes from the United States Department of Agriculture, Washington, D. C. Applicants should write to the department for furthern information.

working of natural processes of importance agriculturally, such as soil erosion; views of different kinds of farm machinery and equipment; views illustrating experiments and demonstration field work carried on by the school. Especially interesting are pictures which show contrasts of good and bad farming methods. It will be found that a good picture collection of this sort will prove to be exceedingly useful.

CHARTS AND MAPS.

Much more use can be made of charts in the teaching of agriculture than is usually done. They can be used to record formulas and data which may be wanted again at some future time, but which are likely to be lost if placed on the blackboard where they may be erased. Thus, plans for the reorganization of farms of the vicinity may be worked out by the pupils and charted for future reference; schemes for proper system of crop rotation on these farms may also be charted; formulas for fertilizer compounds or spraying mixtures may be written on a chart and kept for reference; and drawings of various kinds, such as those showing the various cuts in a beef carcass, may thus be prepared for general use (fig. 15).

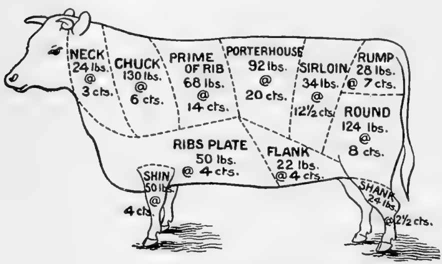

FIG. 15.—Chart showing cuts of beef.

A good chart can be made by the use of heavy manila paper cut into sheets of convenient size, such as 2½ by 3 feet, these sheets being fastened together at one end by nailing them between two pieces of lath. Screw eyes fastened in the ends of one of these laths with a cord tied to them will serve to support the chart on the wall.

Maps for use in the study of agriculture should be chiefly local in character. For most regions topographical maps and soil maps may be obtained. It will be well also to have a map of the forest land of the locality if possible to obtain one.

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UNITED STATES DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN

WASHINGTON, D. C. 713 APRIL 17, 1916

Contribution from the Bureau of Animal Industry, A. D. Melvin, Chief.

SHEEP SCAB.

By MARION IMES, *Veterinary Inspector, Zoological Division.*

CONTENTS.

HISTORY AND CHARACTERISTICS.

Scabies in sheep, commonly known as sheep scab, is one of the oldest known, most contagious, and most injurious diseases affecting sheep. Its history dates back to the earliest ages of civilization. It is a highly contagious skin disease, easily transmitted from one sheep to another, and spreads very rapidly after being introduced into a flock. It is caused by a small animal parasite, commonly known as a "mite," which lives on the skin. Although the disease is not hereditary, it is possible for a new-born lamb to become infected from a diseased mother shortly after birth, and this fact has led some sheep owners to think it is hereditary. Besides common sheep scab there are several other varieties of scab affecting sheep, each caused by a distinct species of mite, but they are of comparatively little importance and will not be considered in this bulletin.

When allowed to spread, sheep scab causes great financial loss to the industry. These losses are caused by (1) a decrease in the quantity of wool produced, (2) loss in weight and general condition from irritation and other effects of the disease which render the animals unthrifty, and (3) the death of large numbers of infected sheep.

NOTE.—This bulletin is intended for the information of sheep raisers and live-stock sanitary officers concerned in the prevention, cure, or eradication of sheep scab. It supersedes Farmers' Bulletin 159.

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While the disease is highly contagious, insidious in its nature, and severe in its effects, it yields readily to proper treatment and is easily cured. A sheep owner should never allow scab to remain in his flock, as it can be easily eradicated by proper dipping.

Common scab was formerly the greatest drawback to the sheep industry of the United States, but during the past decade great progress has been made in its eradication. The system of grazing sheep on the open ranges of the western part of the United States was such that the flockmasters had great difficulty in keeping the flocks free from scab. The sheep were very frequently exposed to the disease by infectious ranges and trails, "picking up strays" from infected flocks, and in many other ways. It became desirable for the Department of Agriculture to extend aid to the industry by controlling the interstate movement of sheep to prevent the carrying of the infection from one State to another. Arrangements for cooperative work with the live-stock sanitary authorities of the various States concerned were made by the Bureau of Animal Industry with the object in view of completely eradicating the disease. This work has been in progress for about 10 years, and during that time the disease has been reduced to a minimum over the entire area and nearly all the formerly affected States have been released from quarantine. The disease has been so nearly eradicated that at present the economic losses from this cause are practically nil. In view of the highly contagious nature of the disease, however, it is very important that the work of eradication be pushed to completion in order to prevent the disease from again becoming prevalent.

With our present knowledge of and experience in sheep-scab eradication work, it is comparatively easy to reduce the infection to a point where it ceases to cause economic loss, but the complete eradication of the parasite over such vast areas is a problem requiring patience and diligence. Where the eradication work is supervised by a well-organized force of trained field men, the percentage of infected flocks can be reduced very rapidly until it reaches a fraction of 1 per cent; but to reduce that fraction to zero requires very careful and systematic work, with the full cooperation of the sheep owners. As soon as the disease is reduced to a point where the economic loss is little or nothing, many sheep owners lose sight of the importance of continuing systematic efforts for complete eradication. It is necessary, however, for the protection of the sheep industry that the efforts be continued until the pest is completely eradicated.

Since the quarantine has been removed and compulsory dipping discontinued the sheep owners in some communities have allowed their dipping vats to go to ruin through lack of use and care. All vats should be kept in repair, and for several years to come each sheep owner will probably find it wise to dip his sheep at least once a year as a precautionary measure.

THE PARASITE WHICH CAUSES SHEEP SCAB.

The mites which cause common sheep scab are small insectlike parasites known technically as *Psoroptes communis ovis* or *Psoroptes ovis*, the male measuring when fully grown only about one-fiftieth and the female one-fortieth of an inch in length. They may be seen with the naked eye, particularly if they are placed on a dark background. They occur on any portion of the body covered by wool, but are most common where the wool is thickest; they are the sole cause of the disease. (See figs. 1 and 2.) Their destruction is followed by recovery, whereas any treatment which does not destroy them fails to cure scab.

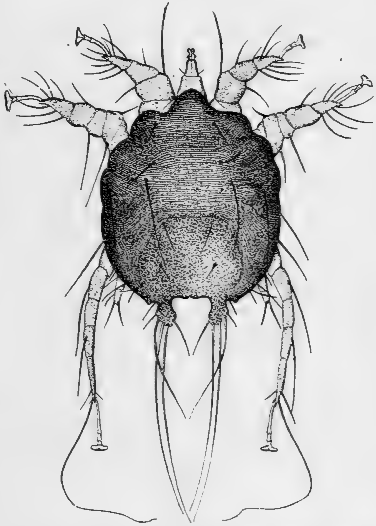

Fig. 1.—Sheep-scab mite (*Psoroptes ovis*). Male. Dorsal view, greatly enlarged. (After Salmon and Stiles, 1898.)

LIFE HISTORY OF THE SCAB MITE.

The various stages in the life history of the scab mite are all passed on the body of the sheep. After the mating of the sexes the females deposit their eggs in clumps on the skin at the base of the wool fibers. Each female may deposit at least as many as 15 eggs, which hatch after 3 or 4 days' incubation; the young mites grow to maturity in 7 or 8 days and in 3 or 4 days more mate and deposit their eggs. The females apparently live but a short time after they have laid their eggs.

According to the figures above, which are those given by Gerlach, the entire life cycle is completed in 12 to 15 days. Other observers state that the period of incubation of the eggs may be as long as 10 days, but this is probably exceptional, and 7 days may be assumed to be the usual maximum limit of incubation. Assuming that each female has 15 offspring and taking 15 days as the period required for each brood of eggs to hatch and the young mites to develop to maturity and deposit another brood of eggs, Gerlach has estimated that the sixth generation from one pair of mites, which may appear in 90 days, may consist of as many as a million and a half individuals. Another 15 days may bring the number up to 15,000,000 and 15 days more to 150,000,000. This calculation, though theoretical and only approximate, gives an idea of the rapidity with which these parasites multiply and shows that a few mites gaining a foothold on one or two sheep may in a short time have descendants enough to infest heavily the entire flock. The importance of prompt treatment when scab is discovered in a flock, or if sheep have been exposed to infection, is evident.

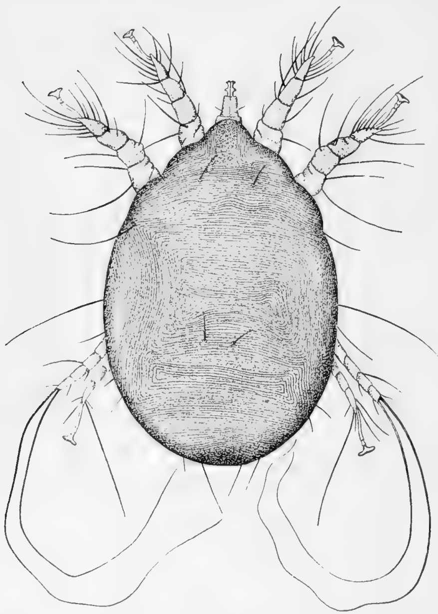

FIG. 2.—Sheep-scab mite (*Psoroptes ovis*). Female. Dorsal view, greatly enlarged. (After Salmon and Stiles, 1898.)

Some of the points in the life history of the scab mite, as outlined above, have a certain bearing on the question of the time which should elapse in the treatment of sheep scab between the first and second dippings. It has been found that a single dipping usually fails to free a flock from scab, the apparent reason being either that all the females in the course of depositing eggs at which time they appear especially tenacious of life) or all the eggs already deposited have not been destroyed by the dipping; consequently, after the eggs which may have escaped the first dipping have had an opportunity to complete their incubation, it is essential to dip the sheep again. It is also essential that the second dipping take place before any mites which may hatch out after the first dipping have had time to become mature and deposit more eggs. As the eggs on the body of the host usually require 4 days' incubation, sometimes a week, and probably never more than 10 days, and as 10 to 12 days are necessary for the young mites after hatching to grow to maturity, mate, and deposit their eggs, it would appear that the best time for the second dipping is about 10 days after the first, as all the eggs will have hatched, while practically none of the new generation of mites will have developed sufficiently to deposit eggs. Practical experience has shown that the second dipping may be delayed until the fourteenth day without unfavorably affecting the results of the treatment, but wherever possible it is preferable to follow the 10-day rule.

VITALITY OF SCAB MITES.

The species of mite which causes common sheep scab is unable to propagate itself except on the bodies of sheep, its natural host. Mites of this species, however, when removed from the host, are able to live for some time, the period of survival varying under different conditions.

From a practical point of view and because of the spread of infection from diseased to healthy sheep through the medium of stables, pastures, etc., and the fact that the mites or their eggs, scattered by diseased sheep, may survive until picked up by healthy sheep, this question of the length of time that mites or their eggs may retain their vitality when away from the host is obviously an important one. Various data which have been collected relative to this subject show that mites removed from the body will commonly live from 2 to 3 weeks, and cases have been recorded of their survival for as long as 2 months. It appears certain that under natural conditions they sometimes live much longer.

A dry atmosphere is very unfavorable to their existence away from their host. Other things being equal, scab mites will live longer off the body in a cool, moist atmosphere than in a warm, dry one.

Owing to varying conditions which may affect the longevity of mites and the vitality of their eggs when away from their natural host, it is impossible to make definite statements as to the length of time infection of pastures and buildings may persist after sheep have been removed from them. It is fairly safe to assume, however, that a month or two will suffice to free open pasture from infection, but that buildings, pens, bed grounds, etc., will not be safe even after a year or more; consequently these latter places, when they have been occupied by infested sheep, should be abandoned, destroyed by burning, or thoroughly cleaned and disinfected before they are used for clean sheep.

SYMPTOMS OF SCAB.

When the scab mite finds lodgment on a sheep it pricks the tender skin to obtain food, and in so doing probably introduces a poisonous saliva into the wound. A slight inflammation is caused, made manifest by a reddening of the skin. This stage of the disease is rarely if ever detected by casual observation. (See fig. 3.) As the mites multiply, large numbers of small wounds are made in the skin and are followed by intense itching, with formation of papules, inflammation, and exudation of serum. The serum, which oozes to the surface, becomes mixed with the natural excretions and particles of dirt, and more or less infested with microorganisms. This mass soon hardens into crusts or scabs in the wool; these in the early stages are of a yellowish color, but as the disease advances and the scabs thicken they become dark from blood stains, dirt, and other causes. When the disease begins only a small pimple can be seen, but as the mites

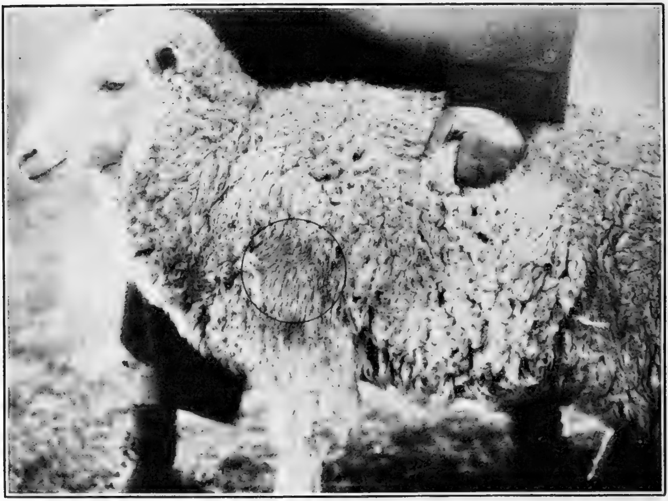

FIG. 3.—First stage of scab on shoulder, showing natural position of wool disturbed by biting and scratching.

multiply they seek the healthier parts around the edges of the diseased area, and thus the lesion or scab is continuously enlarged. The areas of the skin affected become hardened and thickened. This is readily detected by pinching up a portion and comparing it with the surrounding healthy skin. Other conditions resembling scab rarely if ever cause this characteristic, uniform thickening of the skin. When the affected skin is pinched or handled, the sheep as a rule turns its head toward the lesion, thrusts out the tongue, licks the lips, and champs the jaws.

The intense itching causes the sheep to become restless. This irritation is particularly noticeable after the animals have been driven, as itching is more intense when they are heated. They bite and scratch themselves and rub against any available object, including other members of the flock. The natural position of the wool is disturbed by these efforts to obtain relief, and as more or less wool is pulled out, the fleece assumes the condition known as "broken." At first the wool on the affected parts, if within reach of the mouth, is seen to have been chewed and some of it pulled out. The wool on affected parts not within reach of the mouth has a discolored, worn, or ragged appearance, caused by scratching with the hind feet or

FIG. 4.—First break in fleece, early stages of scab, lesions about the size of a pea.

rubbing against other objects. At this stage the marks of the mouth or feet on the fleece or the disturbed position of the wool may be the only visible symptoms, unless close examination is made of each individual sheep. (See fig. 5.) As the disease advances increasingly large areas become entirely denuded of wool. Scabs fall and are replaced by thicker and more adherent crusts. The skin finally becomes more or less bare, tumefied, is greatly thickened, and may crack and bleed. Unless properly treated many of the animals will die.

DETECTING SCAB IN THE EARLY STAGES.

The most certain diagnosis consists in demonstrating the parasite (*Psoroptes communis ovis*) which alone causes the disease. To obtain specimens of live mites one of two methods is usually employed; first, lifting the mite from the surface of the skin with the point of a knife blade, and second, taking scrapings of wool and epidermis containing the mites and isolating the parasites from such scrapings. To obtain mites with a knife blade, good light is necessary. The wool around the affected area is suddenly parted with the forefinger and thumb, and by the aid of a magnifying glass or even with the naked eye the mites can often be seen moving rapidly away

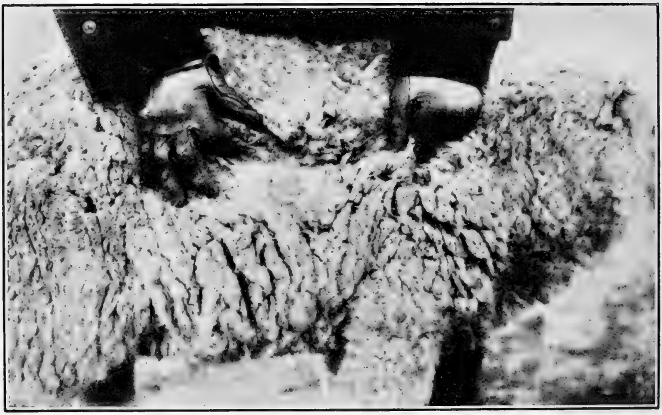

FIG. 5.—Characteristic scab lesion in early stages of the disease.

from the light. When they are thus found they can often be picked up on the end of a knife blade.

When scrapings are taken the outer edges of the infected areas should be scraped with a blunt-edged knife. The mass of scrapings is transferred to a smooth, black surface such as the brim of a black hat or a piece of black paper. To make the mites active the temperature should be approximately the temperature of the body. Spreading the scrapings in the bright, warm sun or near artificial heat will usually cause the mites to become active, and they can be seen as minute gray moving bodies against the dark background. They are quite plainly visible under a low-power hand lens.

When the mites are producing active irritation the surface of the skin in the immediate vicinity of the lesion is greasy and appears bright and glistening or white and glossy. Under such conditions the mites are usually present in large numbers and are easily found. On the other hand, if the lesion is dull and dry in appearance it indicates that the mites are inactive at that point and that they will be difficult to find. Usually the latter condition is found in the center of a patch of scab of comparatively long standing or where the mites have been destroyed or rendered dormant. The white, glossy appearance is seen in cases of recent infestation or on the outer edges of old lesions. It is often difficult to find mites during cold, stormy weather, as they apparently leave the infested area, where the wool is light, and seek shelter where it is heavier.

Any condition which causes the sheep to bite and scratch should be investigated at once and the cause definitely learned. Scab on certain parts of the sheep's body may be overlooked. It is usually found on the back or sides, but may start on any part of the body. Lambs are sometimes infected around the head between the horns and ears, and as these parts are frequently covered with dirt the lesions may not be noticed unless close examination is made. Scab mites are sometimes found in the ear and in the groove beneath the eye, which may explain some cases of fresh outbreaks after treatment, the mites in these places surviving imperfect dipping. On wrinkled breeds, and especially on the bucks of these breeds, scab may be so well concealed in the wrinkles as to render its detection difficult. The breasts and bellies of suspected bucks of all breeds should be closely examined, as these parts are frequently affected. In some cases a considerable area of scab may be present, especially on the back of the sheep, without causing a break in the fleece. In these cases, most often found in tight-wool sheep, the wool will be "raised" from the skin but is held so firmly by the surrounding wool that it may escape detection. Bucks are not so sensitive to the effects of scab as other sheep; consequently they may have scab a long time without showing any breaks in the fleece. In some cases they do not bite or rub the affected parts enough to cause dislodgment of the wool. (See fig. 7.)

Well-advanced cases of hard scab are usually easy to diagnose, but the disease should never be allowed to reach this stage, as it entails heavy loss to the owner and the entire premises may become infectious. The experienced sheep grower realizes that a case of common scab, if neglected and allowed to spread, will materially reduce the profits and often place the balance on the wrong side of the ledger.

CONDITIONS WHICH MAY BE MISTAKEN FOR SCAB.

Any parasite or condition which causes itching and thus leads the sheep to scratch themselves may temporarily be mistaken for scab, but if it is remembered that scab is caused only by scab mites, and that unless they are present there can be no scab, the diagnosis is rendered more simple.

Common sheep scab may be differentiated from conditions caused by other parasites, such as sheep ticks, common ticks, and lice, by finding the parasite and by the nature of the lesion. If the itching is caused by ticks an examination will reveal the ticks. (See fig. 8.) They are much larger than the scab mites and are of a dark-brown color. If lice cause the sheep to scratch they can be found on examination, and as they are much larger than a scab mite they are

FIG. 6.—A case of scab more advanced than that in figure 5, showing area denuded of wool.

easily identified. Ticks and lice do not, as a rule, produce pronounced local lesions. They move more or less from place to place on the skin, so that scratching and biting is not repeated persistently in one place as in the case of scab. It should be remembered, however, that ticks or lice may be present on scabby sheep and that their presence in itself is not enough to warrant the exclusion of scab as a possibility in the diagnosis.

Bearded seeds of grass and weeds, thorns and spines from cacti and various other plants, often become lodged in the fleece and prick the skin, setting up an irritation which causes the animal to bite and scratch. In this way wool is pulled out in small tags and the fleece often presents a ragged or broken appearance. The bearded seeds or thorns sometimes penetrate the skin, causing an abscess. On close examination the causative agent can usually be found and removed.

Eczema, wildfire, summer sores, inflammation of the sebaceous glands, rain rot, shear cuts, sunburn, and the effects of alkali dust on areas denuded of wool may be mistaken for scab by those who are inexperienced.

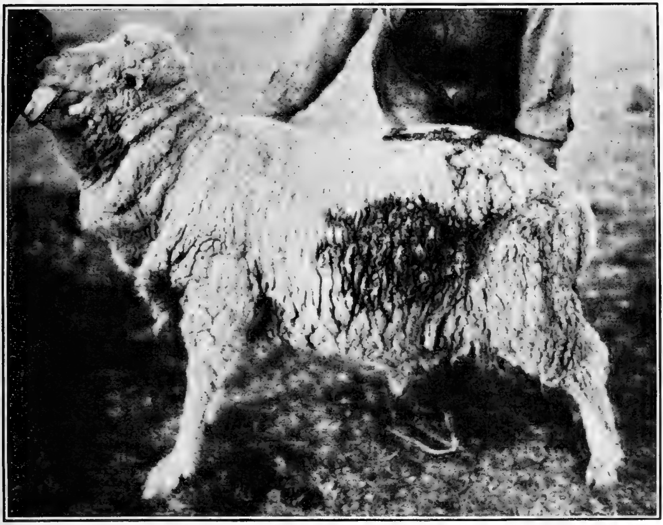

FIG. 7.—Scabby buck with entire hind quarters and flank affected. (The discolored area is due to dip stain from hand dressing.)

Eczema is an inflammatory condition of the skin and is usually accompanied with itching and the formation of crusts and in some cases scabs. It is differentiated from scab by the fact that it does not cause the characteristic thickening of the skin found in common scab and the mite is not present.

Wildfire, so called, affects sheep mainly in the Northwestern States. It causes the sheep to bite and scratch, and the pulling of the wool causes breaks in the fleece. Upon examination of the infected sheep the skin is found to be red and inflamed but is soft to the touch. It is not hardened and thickened, as in scab.

A condition commonly known as summer sores exists among sheep in some localities. It appears as an irritating sore on the skin. The sheep bite and scratch the affected parts until the wool is pulled out and the skin becomes raw and bleeding. It is differentiated from scab by the absence of the scab mite, the character of the lesion, and the fact that the skin is not thickened in the characteristic manner.

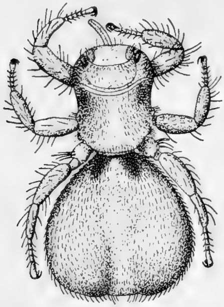

FIG. 8.—Sheep tick (*Melophagus ovinus*). Male. Dorsal view, enlarged. (From Curtice, 1890.)

Inflammation of the sebaceous glands may be mistaken for scab. There is severe itching, the skin is red and sensitive, and there is an excretion of a strong-smelling, yellowish, viscid yolk. The skin does not have the characteristic appearance of scab and the mite is not present.

In rain rot, a condition occurring in rainy weather, an eruption may appear on the skin which might be mistaken for scab. There is, however, no parasite present, itching is absent, and the trouble disappears when dry weather comes.

Shear cuts, sunburn, and the effects of alkali on the skin are conditions found in sheep after shearing. They are easily differentiated from common scab by the character of the lesions and the absence of the scab mites.

CONTAGIOUSNESS OF SCAB.

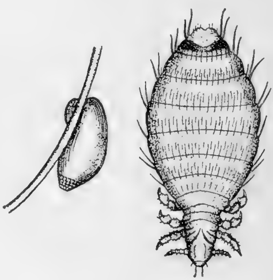

FIG. 9.—Sheep foot louse (*Hæmatopinus pedalis*). Adult female and egg, enlarged. (From Osborn, 1896.)

Sheep scab is exceedingly contagious and is transmitted by direct contact with animals or objects that are carriers of the mites. Although unable to propagate except on sheep, the mites may be harbored temporarily by animals other than sheep and may live on goats for a long period. Consequently, in the eradication of the disease, goats belonging to a flock of scabby sheep should be handled and treated in the same way as the latter. Sheep scab spreads through a flock very rapidly, once it is introduced. The contagion may be direct, by contact of one sheep with another, or indirect, from tags of wool, fence posts against which infected sheep have rubbed, or from places where they have been. A flock of scabby sheep will infect the roads, trails, sheds, yards, bed grounds, pactures, ranges, and the ground around the watering places. It is therefore important that the flock receive proper treatment as soon as the disease appears, before the infection becomes scattered over the premises.

The transmission of the disease to a flock is not limited to any one season of the year, although during the hot summer months few cases of recent infestation are noticed in the range sections. Scab often remains dormant during dry summer months and assumes the appearance of having been cured, but usually becomes evident again with the advent of cold, rainy weather.

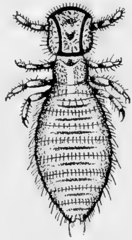

FIG. 10. — Sheep louse (*Trichodectes sphærocephalus*). Adult female, enlarged. (After G. Neumann, 1892.)

Symptoms of scab may develop within a week after healthy sheep have been exposed to it. The usual practice is to consider that the disease may develop at any time within 30 days after exposure, although, under certain conditions, the development may be retarded even longer. The disease develops more rapidly in the fine-wool breeds, such as the Merino and Rambouillet, than in the loose-wool breeds having an open fleece, and the fine-wool sheep also succumb more rapidly to an attack, so that treatment must be very carefully applied if the results are to be successful. The fleece of the fine-wool sheep contains much grease or yolk, which in a measure hinders the penetration of the dip.

The effect of sunlight on the scab mite is apparently an important factor, since the disease develops most rapidly and is seemingly most severe in its effects on the fine-wool sheep, and is diminished in its effects and retarded in its development in a direct ratio as the fleece becomes more open. The Navajo Indian sheep, which have very coarse, open fleeces, resembling somewhat that of a goat, rarely if ever are affected with hard scab. While the infection will remain in a flock of such sheep indefinitely if not treated, the lesions seldom become extensive. In the semiarid sheep-ranging sections of the United States it is a well-recognized fact that if scab is to be detected in a flock examination must be made before or at the time of shearing. If the scabby sheep in these sections are shorn and turned out on the ranges, where the sunlight is very bright, the scabs dry up, drop off, and the lesions apparently heal. Evidently the infection is not destroyed, but remains dormant, as the disease will as a rule break out again under certain favorable conditions. After the wool has grown sufficiently to shade the skin and the fleece becomes wet from rain, the disease usually becomes well marked.

The most important factor in spreading scab infection in the range country is the buck, which is a source of danger too often overlooked. It is the custom in many sections for owners of sheep to put their bucks in a "public buck herd." That is, a number of owners all turn their bucks into one herd and a sheep herder takes charge of this community buck herd and runs it on the open range until within a few weeks of the time when the bucks are to be turned into the ewe flocks. The herd is then split up, each owner taking his bucks home to be fed grain in preparation for the breeding season. These herds usually consist of from 1,200 to 1,500 bucks, representing a large number of owners. Should scab exist in any of the outfits at the time the herd is made up, the entire herd will become infected. Infection may find its way into the buck herd in a number of different ways, and once introduced the disease will be carried into all of the outfits represented, unless the herd is treated prior to disbandment. It is estimated that more than 90 per cent of the outbreaks of scab in the sheep-growing sections of the West can be traced directly to the public buck herds. All such herds should be dipped just prior to the time the animals are to be distributed to the various owners. This is one of the most important points in eradicating scab from the flocks on the open ranges where this custom prevails.

One or more attacks of the disease do not confer immunity, and a flock may become infected any number of times. After a flock has been properly treated and the disease cured by dipping, it may become reinfected, if exposed by contact with infected animals, bedded down on old infectious bed grounds and corrals, driven on trails or roads over which infected sheep have recently passed, turned on to infectious ranges, pastures, or yards where infected sheep have recently been, or in any other manner directly exposed to the infection. As a rule the visible symptoms of reinfection do not appear until after a lapse of 30 days from the date of the last dipping. If conditions are favorable and the sheep are thriving, a much longer period may elapse before they show visible symptoms of disease from exposure to infection after dipping. The dip that is left in the wool after dipping will often serve, for a limited period of time, as a preventive against reinfection. The length of this period of protection varies with the climatic conditions and the kind of dip used. If the sheep are exposed to frequent, heavy rains after dipping, much of the dip will be washed out of the fleece. A dip containing sulphur acts as the best preventive against reinfection. Under average conditions such a dip will probably afford protection for a period of from 30 to 60 days and, under favorable conditions, for a much longer time.

TREATMENT.

The only rational treatment for common scab consists in using some external application which will kill the parasites. Feeding sulphur and salt and various other preparations to sheep will not destroy the parasites and consequently will not effect a cure. Hand dressing, or "spot doctoring" as it is commonly called, consists in soaking the affected parts with a medicated solution of strength sufficient to kill the mites. This acts as a palliative and tends temporarily to check the disease, but will not effect a cure. The only conditions under which hand dressing can be advised are (1) when the disease develops in a few sheep of the flock during severe winter weather or just prior to lambing, in which event the infected sheep should be isolated from the flock and may be given a hand dressing to keep the disease in check until arrangements can be made for dipping the entire flock; (2) all sheep affected with hard scab should be separated from the flock just prior to dipping and the crusts or scabs broken up with a cob or stick and the spots soaked well with dip a little stronger than is used in the bath. It can not be too strongly emphasized that hand dressing, or spot doctoring, will not cure scab; in fact, in many cases it is responsible for spreading the disease, for the reason that the sheepman too often depends on this method to effect a cure. Meantime the disease is spreading throughout his flocks and the premises occupied are becoming infectious. Temporizing methods in dealing with sheep scab are expensive in the long run and should never be used or depended upon.

DIPPING SHEEP.

Dipping consists in immersing the sheep in a medicated solution that will kill the parasites, and is the only practical method known for eradicating the disease from the flock. The usual method is for the sheep to enter one end of a vat filled with dip, through which they swim, and leave the vat at the opposite end. The dip or solution should be used warm in order that it may penetrate the fleece and the hard scabs or crusts. Two dippings 10 to 14 days apart are necessary to effect a cure. The first dipping kills the live mites but does not destroy the eggs. Within 10 days after the first dipping the eggs on the skin at that time will have hatched out, but the new mites will not have reached maturity or laid eggs. The second dipping kills the new mites hatched subsequently to the first dipping.

As a basis of practice it may be stated that one dipping will not cure scab. Sheep in full fleece will retain more of the dip in the wool than freshly shorn sheep or lambs with short wool. If the active principle of the dip used is only slightly volatile and the sheep have heavy fleeces, one dipping will sometimes effect a cure. The reason for this is that sufficient dip remains in the wool to kill the new crop of mites. One dipping, however, can not be depended upon to cure the disease, and it will fail to do so in the large majority of cases. It will certainly fail unless conditions are just right; consequently all scabby sheep should be given two dippings with an interval of 10 to 14 days between dippings. The entire flock should be dipped regardless of the number showing infection. To pick out the ones showing scab and dip no others will result in failure, as the disease will continue to develop in the undipped portion of the flock.

If the dipping is to be successful it is necessary to give close attention to the details and to see that the work is carefully and

FIG. 11.—Dipping sheep in cement vat, showing entrance.

thoroughly performed. Sheep should not be dipped immediately after shearing; a period of at least 10 days should elapse between shearing and dipping, in order that the shear cuts may heal. It is dangerous to dip sheep in some of the dipping preparations, especially lime-and-sulphur, if there are any fresh wounds on the animals; consequently dogs that bite the sheep should not be allowed in the dipping corrals. The chutes, pens, and dipping vat should be closely examined for nails, broken boards, or any object that may puncture or wound the skin of the sheep. Animals having fresh wounds when dipped in lime-and-sulphur usually develop a condition commonly known as "blood poisoning," and the mortality from this cause is high. It does not occur unless there are fresh wounds on the skin. After the wounds have granulated or healing is well started there is little or no danger from this cause. Rough handling of the sheep at the time of dipping results in more harm and damage to the flock than is caused by the dip. When sheep are placed in the dipping vat by hand the men handling them should be instructed to do so carefully. They should not be allowed to catch the sheep by the ears; this is sometimes done and has resulted in breaking or bruising the skin, causing the heads to swell after dipping and resulting in considerable death loss.

Ewes and lambs should not be dipped together. The lambs should be "cut out" and dipped separately, and they need not be held in the swim so long as the older sheep. If the ewes and lambs are put into the vat at the same time, the danger of drowning some of the

FIG. 12.—Dipping sheep in wooden vat, showing exit.

latter is much greater than when they are dipped separately. It has been stated that the ewe recognizes her lamb more readily when they are dipped together; this, however, is probably not correct. A ewe recognizes her lamb by smell and not by sight, consequently after the flock has been dipped and the ewes and lambs have been turned in together there is considerable commotion for a time, as the ewes fail temporarily to recognize their offspring. However, the members of the flock will adjust matters for themselves, and, as a rule, practically every lamb will be recognized by a mother. It often happens that an undipped sheep will jump out of the pens and get in with those that have been dipped. This should be carefully guarded against and all such sheep dipped before the flock leaves the vat. By looking the dipped sheep over it is easy to detect any undipped sheep that may have gotten in with the dipped ones.

Prior to bringing the sheep to the vat for dipping they should be watered and fed so as not to be thirsty or hungry at the time of dipping, although they will probably stand the effects of dipping better if not too full of feed and water at the time dipped. If they are watered and fed 3 to 6 hours before dipping, they will probably be in the best condition for the operation. When the weather is cold or stormy, dipping operations should be commenced early in the morning and finished for the day in time to give the last sheep dipped opportunity to dry off before night. During winter weather dipping for the day should be finished by noon so that the flock may have time to dry off and fill up with feed before night, as a sheep with a full stomach will withstand much cold and hardship. By observing these precautions sheep may be dipped with reasonable safety during cold weather.

Bucks should be dipped separately from ewes and lambs. They should not be driven fast and then put into the vat before resting and cooling off. As they succumb very easily in the vat it is necessary to give them careful attention. Hard scab on rams is difficult to cure and they should be held in the swim for 3 to 5 minutes. The hard scabs should be broken up by manipulation so that the dip may penetrate to every part. At the large vats the buck herds are usually dipped first, while the vat is full, so as to afford them more swimming room.

For dipping purposes soft water is better than hard; apparently some of the ready-prepared dips do not mix properly and are not effective with hard water. If hard or "alkali" water must be used it is improved and its effects on scab increased if it is softened or "cut" by adding lye or sal soda, but no more should be added than is required to cut the water. An excess of potash will tend to injure the wool and cause an irritation of the eyes.

DIRECTIONS FOR DIPPING.

The amount of dip in the bath should be sufficient to submerge the sheep completely. The depth of the dipping fluid in the vat should be from 40 to 48 inches, depending on the size of the sheep. The amount of fluid necessary to fill the vat to the required depth should be ascertained before it is prepared. Freshly shorn sheep and short-wooled lambs will carry out on an average from 1 to 2 quarts of dip, depending on the size of the sheep and the length and grade of wool, while full-fleeced, fine-wool sheep will carry out and retain in the fleece as much as 2 gallons. At late fall dipping the average medium-wool sheep will retain in the fleece about 1 gallon of dip. In estimating the amount of dip required, these facts should be taken into consideration. After computing the amount of dip required to charge the vat, the average amount of dip which each sheep will carry out should be estimated; this should be multiplied by the number of sheep to be dipped and the product so obtained added to the amount required to fill the vat. If the vat and draining pens are watertight, so that no dip is lost through these sources, the total as given above should show the approximate number of gallons of dip required to complete the work.

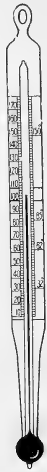

FIG. 13.—Floating dairy thermometer.

The temperature of the dip should not be a matter of guesswork, but should be ascertained accurately by using a thermometer. If it is too high the sheep may be injured, and if too low failure to cure will probably result. In field operations, when the dipping is supervised by inspectors, the temperature of the dip is maintained at 100° to 105° F. Practice has demonstrated that the lime-and-sulphur and nicotin dips should be used at these temperatures. The coal-tar-creosote and cresylic-acid dips should be used at slightly lower temperatures, the maximum for these being 95° F. For use in dipping small lots of farm sheep an ordinary dairy thermometer will answer the purpose. At the large vats where a great many sheep are to be dipped at least two thermometers should be provided as a precaution against breakage and delay. The thermometers used at dipping vats should be tested occasionally by comparison with another thermometer, so as to be sure that they are registering properly. (See figs. 13 and 14.)

FIG. 14.—Thermometer used by Bureau of Animal Industry inspectors, in holder whittled from a block of wood.

After the vat is filled to the required capacity the contents should be well mixed by stirring, in order that the temperature may be uniform throughout. A good method of stirring the dip in large vats is to take a 5-gallon pail or dip container, punch holes near the top, insert a wire for a bail, allow the can to fill and partially sink, then drag it rapidly from one end of the vat to the other, and repeat the process until the temperature is uniform as shown by temperatures taken at several points in the vat. Stirring plungers are useful implements, and, as they are easily made, one or more should be provided at every vat. They are used in a manner similar to the movement of the dasher of an old-fashioned hand churn. The plunger is pushed to the bottom of the vat and raised rapidly, the process being repeated as the operator moves slowly along the vat. The style shown in the cut is the one most commonly used. (See fig. 15.) The dip should be changed as soon as it becomes filthy, regardless of the number of sheep that may have been dipped in it. In emptying the vat the entire contents should be removed, including all sediment and foreign matter. After the liquid portion has been dipped out or drained off the sediment and dirt at the bottom should all be removed and the bottom cleaned by sweeping or scraping with a hoe or spade. After the lime-and-sulphur dip has been mixed to the proper strength for dipping and used in the vat, it should not be used again after it is 10 days old. This is a safe rule to follow with any of the sheep dips, as losses often occur from dipping in old or stale dips.

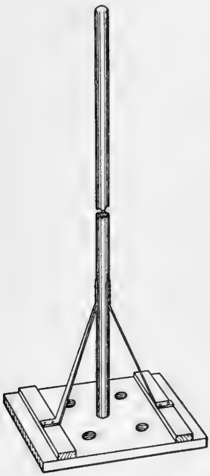

FIG. 15.—Stirring plunger for mixing liquids in the vat.

The time that infected sheep are held in the dip should in no case be less than 2 minutes; if the scab is not advanced, from 2 to 3 minutes in the vat is sufficient. But in well-advanced cases of hard scab on fine-wool sheep, especially bucks, better results are obtained if they are held in the vat from 3 to 5 minutes during the first dipping. If the hard scabs and crusts are broken up and soaked with dip before the sheep are dipped, it is not necessary to hold them in the vat longer than 2 minutes. In all cases in which the scab is advanced it is recommended that the hard scabs be broken and hand dressed with a solution of the dipping fluid so as to soak the affected parts well. In hand dressing such spots care should be taken not to cause the wound to bleed, as the blood will tend to protect the mites from the effect of the dip. After hand dressing such sheep allow at least 1 hour for the scabs to become soaked before placing the sheep in the vat. The time the sheep are in the vat should not be a matter of guesswork. A watch or a 2-minute sand glass should be used to make certain that the animals remain in the dip a sufficient length of time. Where a large vat is used and the sheep are running fairly well it is possible, after a little practice, to arrive at an average working rule as to how many sheep are to pass through the holding gate each time it is raised.

Drowning sheep in the vat can be avoided by proper care. Men with dipping forks should be stationed along the vat on both sides to attend to the sheep and prevent accidents. When the vat becomes filled with sheep their progress is retarded and the tendency is for each sheep to place its front feet on the back of the sheep in front and thus raise its forequarters out of the dip. The men along the vat should prevent this by keeping the sheep properly arranged in the vat. The dipping forks should be used to keep all of the sheep's body submerged but its head while it is passing through the vat; this can be done by placing the dipping fork over the shoulders of the sheep and gently but firmly pushing it under the dip. The animal will raise its nose so that the neck and part of the head can be submerged without danger of strangling. Old ewes that have been dipped a number of times are sometimes difficult to handle, both in the chutes and in the dip. They will often lie on their sides in the vat, bracing themselves with their feet against one side and their backs against the other. When pushed under they will make efforts to regain this position and may strangle. Sheep that are affected by eating loco weed often drown in the vat unless they are piloted through. When strangling occurs the sheep should be taken from the vat. If it does not get upon its feet, pull the tongue forward, dash cold water over the head and body, and, if necessary, induce artificial respiration. When it has acquired sufficient strength, and if it has not been in the dip long enough, the animal should be returned to the pens and piloted through the vat again.

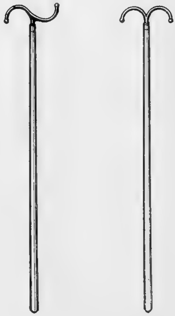

FIG. 16.—Two styles of dipping forks.

DIPPING FORKS.

In using large vats dipping forks are necessary for the efficient handling of the sheep and should be provided as part of the equipment at every plant. There are a number of different styles made, but the two shown in the illustration are the ones commonly used. The one with both hooks turned upward seems to have the preference for the reason that when it is in use either side may be hooked under the neck of the sheep for raising the head in case of strangling. (See fig. 16.) The handles should be strong and from 5 to 6 feet long. The hooks should be made of half-inch round iron and firmly held in the handle by an iron ferrule. These forks can be bought ready-made or may be made by any blacksmith.

EXPENSE OF DIPPING.

The cost of dipping naturally varies in different sections; it also varies in the same section, depending on the number of sheep to be dipped, the location relative to the necessary supplies, and the facilities available for the work. The labor, fuel, and cost of the materials are the three principal items of expense. In the sheep-growing sections of the West the average cost of dipping sheep varies from 2 to $3\frac{1}{2}$ cents per head for each dipping.

CHOOSING A DIP.

There are many dipping preparations on the market. The farmer or sheepman should not be deceived by exaggerated statements made by manufacturers. He should know the nature of the dip he is using and its effects upon the sheep when used in the kind of water which he has available. If a ready-made dip is to be used, one should be selected that will kill the parasites and not cause undue injury to the sheep. Almost any of the better-known ready-prepared dips will prove satisfactory if used according to directions and with pure water. If the dipping plant is not supplied with pure, soft water, a dip should be selected that will work well in the kind of water available. Lime-and-sulphur dip mixes properly and is effective with almost any kind of water. The coal-tar-creosote and cresylic-acid dips apparently do not mix uniformly with some of the hard waters, and they should not be used with such waters.

The dips on the market to-day can be divided into five general groups—those containing arsenic, the cresylic-acid group, coal-tar-creosote dips, nicotin, and lime-and-sulphur. Of these the Bureau of Animal Industry recognizes only two groups for the official dipping of sheep for scabies, namely, lime-and-sulphur and nicotin-and-sulphur.

It has been determined from actual experience over a large field that dips deteriorate by use; that is, after a number of sheep have passed through the vat the active principle of the dip falls below the standard required for effective work. In order to overcome this difficulty and keep the dip up to standard while being used, chemical testing outfits have been designed that can be used at the vat to determine the percentage of the active principle in the dip at any time.[1] In this way the strength can be kept up to the required standard. Before approving a dip for use in the official dipping of sheep, one of the requirements of the Bureau of Animal Industry is that there shall be a practical field test for such dip. Of the five general classes of sheep dips named above, excluding arsenical

[1] See U. S. Department of Agriculture Bulletin 163, A Field Test for Lime-and-Sulphur Dipping Baths, by Robert M. Chapin. Washington, 1915.

dips for other reasons, the lime-and-sulphur and nicotin-and-sulphur are the only ones for which at present we possess a practical field test.

Whatever dip is selected, the sheep grower should not forget the fact that there are two ways of using it. One way is to use it according to directions given; the other way is to attempt to economize time, labor, or money by using it in weaker proportions than advised and by hurrying the sheep through the swim or failing to dip all the sheep in the flock. If the former method is adopted with any of the established dips the treatment should result in a cure. If the latter method is followed failure to effect a permanent cure will result regardless of what kind of dip is used. It is a loss of time and money to dip sheep unless the work is done properly. Desired results can be accomplished only by performing every part of the work thoroughly and in accordance with approved methods.

PREPARATION OF DIPS.

If a ready-made dip is selected it should be prepared and used in accordance with the printed instructions on the label.

THE LIME-AND-SULPHUR DIP.

The lime-and-sulphur dip is made in the proportion of 8 pounds of unslaked lime (or 11 pounds of commercial hydrated lime, not air-slaked) and 24 pounds of flowers of sulphur or sulphur flour to 100 gallons of water. Place the lime in a watertight, shallow box and add sufficient water to form a thin paste. Sift the sulphur into this and mix well until a paste of about the consistency of mortar is formed, adding water as required. Place this lime-and-sulphur paste into 30 gallons of boiling water and boil for at least 2 hours, adding water from time to time to maintain the quantity at 30 gallons, or in that proportion. During the boiling process the mixture in the boiling tank should be stirred well to prevent the paste from settling and caking on the bottom of the tank; the boiling process should be continued until all sulphur disappears from the surface. A large mortar hoe is a good implement with which to stir the boiling mixture. The lime and sulphur should both be weighed; do not trust to measuring them in a pail or guessing at the weight. It sometimes happens that the sulphur is not all "cut" or dissolved: this is especially true if the lime is not of first-class quality. Those who have had considerable experience in the preparation of lime-and-sulphur dip sometimes add small quantities of extra lime if during the cooking they see that the sulphur is not being "cut" properly. It is advisable, however, for the beginner to hold strictly to the formula laid down, as an excess of lime in the dip will tend to injure the sheep and the wool. After the mixture has been boiled for 2 hours the liquid should be of a chocolate or dark-amber color.

The contents of the boiling tank should be drawn off or dipped out and placed in the settling tank and allowed to stand until all sediment has settled to the bottom and the liquid is clear. The use of some sort of settling tank provided with a bunghole is an absolute necessity, unless the boiler is so arranged that it may be used for both boiling and settling. An ordinary, water-tight barrel will answer very well for a settling tank at small vats. All settling tanks of every nature should have an outlet at least 4 inches from the bottom in order that the clear liquid may be drawn off without its becoming mixed with any of the sediment. (See fig. 17.) Drawing off the liquid as above indicated has an advantage over dipping it out, for the reason that in the latter case the liquid is stirred more or less and mixed with the sediment. The prime object is to get the clear liquid without any sediment; the latter should under no circumstances be allowed in the dipping vat, as it will injure the wool and the eyes of the sheep.

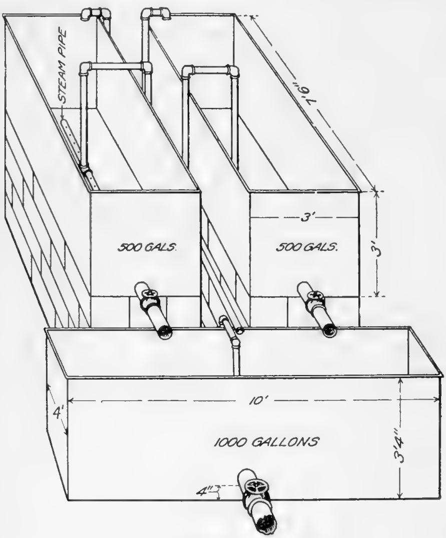

FIG. 17.—Cooking and settling tanks.

When fully settled draw off the clear liquid into the dipping vat and add warm water sufficient to make a total of 100 gallons of dip. When mixed and cooked as above specified the concentrate is 3⅓ times the strength required for the dip in the vat, so that to every 30 gallons of such concentrate 70 gallons of warm water should be added to make a dip of the required strength.

In preparing lime-and-sulphur dip in large quantities several hundred gallons of concentrate are often made at one time in a single large cooking tank. The amount made at one boiling is limited only by the facilities at hand. If the boiling tank is of sufficient capacity enough lime-and-sulphur paste should be cooked at one time to dip the flock. The quantity of mixture in the cooking tank may be varied at will, but the proportions of the various ingredients should not be altered.

THE NICOTIN-AND-SULPHUR DIP.

The nicotin-and-sulphur dip is made with sufficient nicotin solution and flowers of sulphur to give a mixture containing not less than five one-hundredths of 1 per cent (0.05 per cent) nicotin and 2 per cent sulphur. Sufficient nicotin for 96 gallons (about 800 pounds) of dip would therefore be furnished by 1 pound of a 40 per cent solution of nicotin. The formula for this dip would be: Nicotin, four-tenths of a pound; flowers of sulphur, 16 pounds; water 96 gallons.

To calculate how much nicotin solution should be used for 96 gallons of water, divide the quantity of nicotin required in the dip by the proportion of nicotin in the product. For example, suppose the nicotin solution contains 25 per cent nicotin, we have $0.40 \div 0.25 = 1.6$. Therefore in this case it would require 1.6 pounds of nicotin solution for the 96 gallons of dip. No preparation the strength of which is not given on the outside of the package should be used.

In preparing these dips the nicotin solution and sulphur should be mixed together with water before adding them to the water in the dipping vat. The dip should on no account be heated above 110° F. after the nicotin solution is added, as heat is liable to evaporate the nicotin and weaken the dip.

DETERMINING CAPACITIES.

One of the first steps in opening a dipping plant is to ascertain the capacity of the vat and the various tanks. The capacity of the vat is usually obtained in the following manner: In 1 gallon there are 231 cubic inches; multiply the average length by the average width in inches, then the product by the depth; this will give approximately the number of cubic inches of space to be filled with dip. Divide this by 231 and the result will be approximately the number of gallons of dip required to charge the vat.

To obtain the average length, add the length at the bottom to the length at the top (that is, at the line to which the vat is to be filled) and divide this sum by 2. Obtain the average width in the same manner. The depth should be taken at the center of the vat, and should be from bottom to dip line only and not to the top of vat. Likewise in determining the length and width measure only the space to be filled with liquid and not above that line. The capacities of the various tanks are obtained by a like process. Gauges or rods should be prepared and marked to show the number of gallons at various depths in the vat and tanks.

INJURY FROM DIPPING.

Dipping often results in a slight setback to the sheep. There may be a temporary shrinkage in weight, constitutional disturbances, or both. Usually there are various factors operating to produce these conditions. They may occur with any of the standard dips, but should not always be attributed to the effects of the dip alone. The age and physical condition of the sheep, the method of handling the flock at the vat as well as before and after dipping, the character of the water used, the method of preparing the dip, and various other factors should be given consideration before placing the blame on the dip. Young animals in a thriving condition recuperate very rapidly from any temporary ill effects; while old, weak, or emaciated animals succumb very readily and regain lost weight slowly. Injury caused by dipping is more liable to result from improper methods of dipping and handling than from the direct effects of the dip. Rough handling of the sheep in the corrals and legging pens, dipping the flock immediately after a long, hard drive before they have rested and cooled off, dipping late in the afternoon when the nights are cold, keeping the sheep without feed and water for long periods before and after dipping, using dogs in the corral, and fighting stubborn sheep to get them into the chutes, are some of the contributing causes of injury.

Much of the water in the range country carries various amounts of mineral salts, and is commonly known as "alkali" water. Some of the dips do not seem to mix properly with many of these waters and when they are used a separation apparently occurs, so that part of the sheep get too much of the active principle of the dip with resultant injury or death, while others get less than is required to kill the parasites. The lime-and-sulphur dip is about the only one that is safe to use with very impure water, although the nicotin dips mix well and are effective with most waters. Any of the dips if used too strong will injure the sheep.

In practical operations it is an established fact that lime-and-sulphur and possibly other dips are liable to cause serious injury to sheep if there are any puncture wounds. A condition commonly known as "blood poisoning" is produced, probably caused by micro-organisms entering the tissues and the action of the dip searing or sealing the wound so that the air is excluded and drainage stopped. Pure lime-and-sulphur solution will not injure a sterile wound. The dip does not directly cause the "blood poisoning," but acts only as a contributing cause and can be avoided by allowing wounds to granulate or heal before dipping. It may be stated that experience has demonstrated that when sheep are properly dipped in accordance with the rules of best practice in any of the approved dips, the loss or damage is practically nil.

The question often arises as to the proper age at which lambs should be dipped to get the best results and cause the least damage. When the average lamb in a flock is 1 month old it is perfectly safe to dip the flock provided the lambs are dodged out and dipped separately. Any slight shrinkage caused at this time will be quickly regained and the lambs will grow and thrive much more rapidly after being freed of the irritation caused by the scab mites. If the work is properly done and the sheep carefully handled, pregnant ewes may with safety be dipped any time up to within one month of lambing.

There has been much controversy and argument concerning the effects that various dips have on the wool, and many experiments have been conducted and observations made over wide areas. The general opinion among the unprejudiced seems to be that the various well-known dips properly prepared and used injure the wool very little, if any. It is necessary to eradicate scab to make wool growing profitable or even possible. Lime-and-sulphur and nicotin-and-sulphur are among the dips that have proved effective and have been generally used as scab eradicators, both in this and in other sheep-growing countries. It is therefore considered that any slight damage they may cause to the wool is more than equaled by their good effects in eradicating scab.

CLEANING AND DISINFECTING PREMISES.

All premises occupied by scabby sheep will become infectious. Tags of wool which often carry mites and eggs are constantly being pulled out. Old bed grounds, corrals, sheds, or any place where infected sheep have been confined or held until the manure has accumulated are especially dangerous. It is probable that bright sunlight kills the mites, but if they can get under manure or anything that affords shade, moisture, and protection the infection may remain for as long as one year. Sheep free from infection should not be allowed on infectious premises. Old bed grounds, corrals, and other places of close confinement should be avoided unless they have been cleaned and disinfected. Ranges, pastures, trails, and grounds around watering places exposed to the sunlight probably do not, as a rule, remain infectious longer than 30 to 60 days. It is well, however, to avoid places over which infected sheep have passed. Such places, as well as old bed grounds on the range, can not be disinfected, or at least it is not practicable to do so, and therefore they should be avoided. The average sheep herder seems to have a desire to use old bed grounds, and unless means are taken by the owner to prevent it he will continue to bed the flock on old infectious bed grounds after they have been dipped, thus constantly exposing the sheep to reinfection. Corrals, pens, chutes, and sheds can be disinfected, and they should either be cleaned and disinfected or destroyed if they have contained infected sheep. Remove all manure and litter down to a smooth, hard surface and burn the manure and litter so removed or spread on a field and plow under. Spray the entire surface of fences, grounds, and floors, as well as the walls of sheds or buildings, with a disinfectant, such as a coal-tar-creosote or cresylic-acid solution mixed to double the strength recommended for dipping. The work should be well done, otherwise it will not prove successful. All brush corrals on a range where scabby sheep have been should be burned. Corrals of a more permanent nature may be moved to new locations, but the lumber should be disinfected by spraying or passing through the blaze of an open fire before being used.

DIPPING PLANTS.

There are numerous kinds of dipping plants in use, the size and style varying according to the conditions which are to be met and the individual taste of the owner. The farmer who has but a small flock to dip can use a small portable vat as shown in figure 18, turning a part of his barnyard or sheds into catch pens for temporary use, but if he is in the sheep business to stay he will find it advisable to make arrangements of a more permanent nature. Portable galvanized-iron dipping vats, called "hog vats," can be purchased ready-made and will answer the purpose very well for dipping small lots of farm sheep. A dipping bag is sometimes used for dipping when there are only a few sheep to be dipped at different points in a given section. For this purpose it has the advantage of being easily transported. It is made of heavy canvas, known in the trade as No. 40, and is constructed as follows: Two strips of canvas 8 feet long and 26 inches wide are sewed together to form a bag 48 inches deep and 94 inches in circumference. Seams are triple-sewed, top and corners reinforced with leather strips riveted on. (See fig. 19.) Iron rings held by leather ears are riveted to the upper part of the bag as shown in the cut. The bag is filled with dip, the

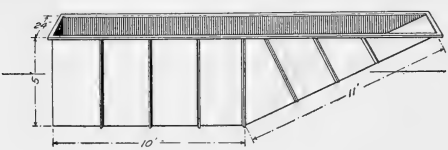

FIG. 18.—Portable galvanized-iron sheep dipping vat.

sheep's feet tied and the animal is set down in the bag and held the required length of time.

Heating tanks or boilers are necessary, the size varying with the number of sheep to be dipped. An ordinary iron caldron or kettle will answer the purpose for a small number of sheep. A rectangular, galvanized-iron tank with large heating surface is preferable. Such a tank is set on two parallel walls, the walls forming the sides, and the bottom of the tank forming the top of the fire box. An opening large enough for the escape of the smoke should be provided at the end opposite that at which the fire is fed.

When large flocks are to be dipped it is necessary to provide proper facilities for the work and a permanent dipping plant is the only practical solution.

FIG. 19.—Dipping bag, made of No. 40 canvas.

SELECTING A LOCATION.

In selecting a location for a dipping plant the fact that sheep work better upgrade should be given consideration, and if possible the ground used for the receiving corrals and chute should slope up to the end of the vat. The vat itself should be on level ground and preferably extend north and south, with the entrance at the south and the exit at the north, as it has been observed that sheep work better when not facing the sun. If the ground selected has good natural drainage it is a point in favor of the location.

CORRALS AND CHUTES.

One of the important points in constructing a dipping plant is the arrangement of the corrals. Here is where much damage is often caused to the sheep and later attributed to the preparation in which they were dipped. The receiving corral into which the sheep are driven preparatory to dipping, as well as the holding corral into which they go from the draining pens, should each be large enough to hold a full band of sheep, or about 3,000 head. The receiving corral should be so constructed that there may be the least practicable number of corners or places in which the sheep may become jammed or "piled up."

The nature of the sheep is such that in an effort to get out it will try to go back to the place where it entered the corral; therefore, if the entrance gate is near the vat the herd will tend to crowd toward the vat and thus save considerable work in getting them into the chute or catch pen. The corrals and chutes may be so arranged that a combination legging pen and running chute is provided. Sheep will usually work well in a chute the first time they are dipped at a vat, but with old ewes that have been dipped several times at the same vat it is often necessary to put them into the vat by hand. The location and arrangement of the chutes are sometimes changed from year to year so the sheep may not recognize them so readily. The running chute should be curved to obstruct the view, and the side on which the men work should be tight boarded. The usual height for the sides of the chute is 40 inches. Sheep work well uphill but not down an incline; the chutes and alleys, therefore, should be upgrade to the vat. If necessary elevate the running chute so that it slants upward to the slide board. A small pen should be provided near the entrance to the vat and so arranged that the sheep may see it. This pen, known as a "decoy pen," is filled with sheep to induce the other members of the flock to work toward the vat more readily in their efforts to join those in the pen. The size and arrangement of the corrals will necessarily vary with the topography of the location and the individual ideas or tastes of the owner.

DRAINING PENS.

When a sheep emerges from the vat it carries out a large quantity of dip in the fleece. The major portion of this dip drains out of the fleece very rapidly and it is desirable that it be saved and returned to the vat. Draining pens with water-tight floors sloping toward the vat should therefore be provided. The size will depend upon the size of the plant and the number of sheep to be dipped. The relative size shown in the plans illustrated in figures 20 and 21, may be followed, increasing or decreasing the size of the pens to correspond to the length of the vat. There should be two draining pens, each having an opening into the holding corral. They may be made of lumber or cement and should have catch basins or screening and settling wells into which the dip drains so as to prevent manure and foreign matter from being carried into the vat. Drawings of screening and settling wells will be found in the plan of the cement dipping plant in this bulletin. (See fig. 21.) In constructing draining pens of cement it is advisable to build the outer walls in the same manner

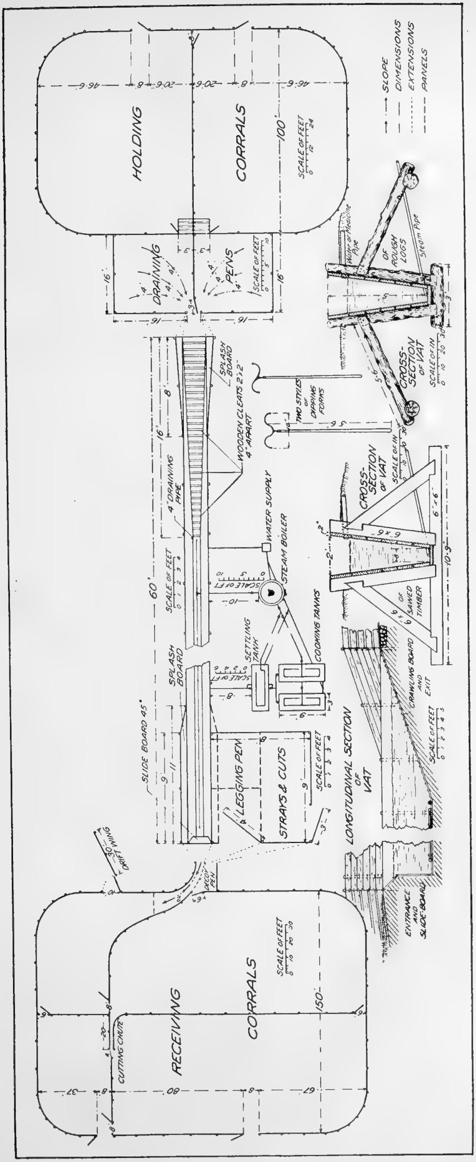

FIG. 20.—Plan of wooden dipping plant.

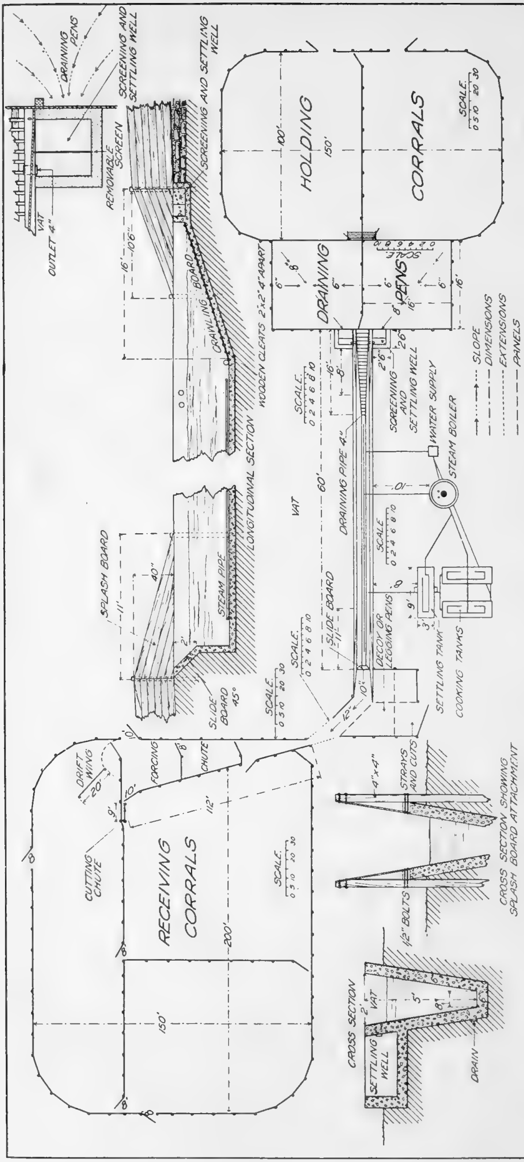

FIG. 21. Plan of cement dipping plant.

as the foundations for a house, except that they are to be 6 inches thick. The space inside these walls is then filled with gravel to the required height and the floor laid on it. Cement floors should have rough surfaces to prevent slipping. A coat of "pebble dash" over the cement floors will afford a suitable surface for the sheep to stand on. The floors of draining pens should slope so that the dip will drain away rapidly and not collect in pools from which the animals may drink.

VATS.

The dipping vat may be constructed of either lumber or cement, the cement vat being preferable. The length of the vat may vary from 30 to 100 feet, depending on the number of sheep to be dipped. Public dipping vats, where from 50,000 to 100,000 sheep are dipped each season, should be 100 feet long. The depth should be 5 feet, width at bottom 8 inches and at top 2 feet. Sheep vats are usually so constructed that the top is flush with the top of the ground and there should be no cross pieces to interfere with free action of the sheep or of the men working along the vat. As a matter of individual taste, however, the top of the vat may extend from 9 to 18 inches above the ground. Those of the latter kind afford a better opportunity to handle the sheep and can be operated with less effort. If it is desired that the top of the vat shall be flush with the ground, it should first be built at least 4 inches above the natural surface of the ground and then dirt or gravel may be filled in, thus securing proper drainage along the sides.

Whenever it is possible to do so the gravity method of draining the old dip out of the vat should be adopted, as otherwise it is necessary to pump or dip it out each time the vat is cleaned. The end of the vat having the drain should be slightly lower than the other end so that all the liquid will drain off. The slide board into the vat should be set at an angle of 45 degrees and extend from the floor of the chute to at least 4 inches below the dip line; it should be made of or covered with a smooth-surfaced material, such as planed lumber or sheet metal. The end extending into the dip should be flush with the vertical end of the vat. A space between the slide board and the end of the vat, if large enough for a lamb to lodge in, is a dangerous arrangement. The runway leading out of the vat should not be too steep. The length varies from 8 to 16 feet, the latter being preferable in large vats.

HEATING FACILITIES.

When lime-and-sulphur dip is used it is necessary to provide cooking tanks. The cooking may be done by steam or in open boilers having a fire box under each. All large plants should have steam boilers of not less than 25 horsepower. The live steam can be piped into the dipping vat and used for maintaining the temperature of the dip and also into the cooking and heating tanks for boiling the dip or heating water. The steam pipes should extend along the floor of the vat at least two-thirds of the length and be provided with openings for the escape of the steam into the dip. The supply pipe from the settling tank should enter the vat above the dip line in order that any leak may easily be detected.

CARE OF PLANT WHEN NOT IN USE.

A dipping plant that does not receive proper care when not in use deteriorates very rapidly. The pressure of the ground against the sides of the vat tends to cause them to bulge inward; this tendency may be counteracted to some extent by keeping the vat full of liquid. Wooden vats which are allowed to stand empty, dry out, and the lumber shrinks so that the vat will leak when refilled. At the close of dipping operations the vat should be left full of liquid and water added from time to time to restore that lost by evaporation.

A week or 10 days prior to beginning dipping operations the entire plant should be overhauled and put in good condition. Before charging a new vat or one which has stood empty for some time, it should be filled with water to ascertain whether it leaks.

CONSTRUCTION OF DIPPING PLANTS.

Plans for the construction of cement and wooden sheep dipping plants are shown in figures 20 and 21. They are not drawn to a uniform scale, consequently, in studying the drawings the scale of each part should be noted. The plants as shown have no superfluous equipment and the arrangements are as simple as is consistent with efficiency. The size of the plant can be increased or decreased as desired. A different corral, chute, and legging pen arrangement are shown with each vat. All parts are interchangeable and are suitable for use with either vat. Cross fences as desired can be added to the corrals. Cutting chutes are shown in both plans, as every large dipping plant should have such a chute equipped with a dodge gate so the lambs may be cut out and dipped separately.

If permanent pipes are used for conducting water and dip to the vat they should be so laid as not to act as an obstacle to the men working along the vat. There should be no obstructions to the path along both sides of the vat. The pipes can be placed under the ground or a portable V-shaped trough can be used for conducting liquids into the vat and laid aside when not in use.

THE WOODEN VAT.

As shown in the plans for the wooden vat, one side of the running chute is made of portable panels so they may be shifted and the space converted into a legging pen. Two styles of framing are shown. In the cedar-growing sections the cedar-post frames are preferable because they do not decay rapidly, while the sawed white-pine timbers do. Where hardwood is used instead of white pine the frame timbers need not be so heavy; 4 by 4 inches is heavy enough for framing in hardwood. The frames are set from 2½ to 4 feet apart, depending on the character of the soil and the material used; 2½ feet apart is a safe rule, as the closer the frames are to each other the less tendency there is for the sides of the vat to bulge in between the frames. Two-inch tongued-and-grooved planks should be used in making the vat, and they should be beveled so all joints and seams may be properly calked with oakum or similar material.

THE CEMENT VAT.

In the plan for the cement plant the corrals and chute are very conveniently arranged. The portable panels can be shifted to form either a running chute or a legging pen. The settling and screening wells shown can also be constructed as a part of any vat by changing the slope of the draining pens so the dip will run into the wells instead of down the runway. In making the forms for a draining well, the groove into which the removable screen is to sit should be provided for, as well as the 4-inch opening into the vat.

The trench for a cement vat should be excavated so the inside dimensions correspond with the outside dimensions of the vat when completed. If the sides of the trench are smooth and reasonably firm, they can be used as the outer wall of the form, but in all cases where the vat is extended above the surface of the ground it is necessary to build forms extending from the surface of the ground to the top of the vat. If the soil is sandy, it will be necessary to build outer forms, in which case the trench should be wide enough to allow for these forms. The drain and other pipes shown in the drawing should be placed in the form and should all be threaded and capped so proper connections may be made. Three pairs of ½-inch bolts should be embedded in the concrete of the incline for attaching the false floor or runway. This floor is made of 1 by 6 inch boards laid lengthwise with cross cleats, as shown in drawings. Two pairs of bolts also should be embedded for attaching the slide board. Steam pipes should not be molded into the concrete walls, as the vibration of the pipes will crack the cement. They should pass over the top of the vat and down the side in a groove formed in the wall, so they will not come in contact with the sheep or cause annoyance to the men working along the vat.

The walls should be made 6 inches thick, constructed of concrete mixed in the proportion of 1 part of cement, 2 parts sand, and 4 parts broken stone or gravel. This mixture is slushed into forms properly set, and when it approaches dryness the forms are removed and the inside surface of the vat coated with pure cement mixed to about the consistency of cream and applied with a brush. It is important that this coating be well brushed in so as to fill all cavities and form a smooth surface. Finishing coats of sand and cement applied with a trowel after the forms have been removed are liable to crack and scale off.

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FLYTRAPS AND THEIR OPERATION

F. C. BISHOPP

Entomologist, Investigations of Insects Affecting the
Health of Animals

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UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

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RESULTS obtained in experiments with the use of chemicals against fly larvæ in manure are presented in Bulletins Nos. 118, 245, and 408 of the Department of Agriculture. The biology of the house fly and the various methods of control are discussed in Farmers' Bulletin 851.

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.

FLYTRAPS AND THEIR OPERATION.

CONTENTS.

USES AND LIMITATIONS OF FLYTRAPS.

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.

It may be said that there are two main ways in which flytraps are valuable: (1) By catching flies which come to clean premises from other places which are insanitary and (2) by 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.

Flytrapping should begin early in the 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, including the screw-worm fly;[1] and (2) those which breed in vegetable as well as in animal mat-

[1] *Chrysomyia macellaria* Fab.

ter. In the latter group the house fly [2] 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 in rare cases may contaminate foodstuffs. The stable fly,[3] which breeds in cow manure or decaying vegetable matter, and the horn fly,[4] which breeds in 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 blow-flies 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.

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 that 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.

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[2] *Musca domestica* L. [3] *Stomoxys calcitrans* L. [4] *Lyperosia irritans* L.

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 $1\frac{1}{2}$ 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 $1. 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 80 cents. If a larger number of traps are constructed at one time, the cost is considerably reduced.

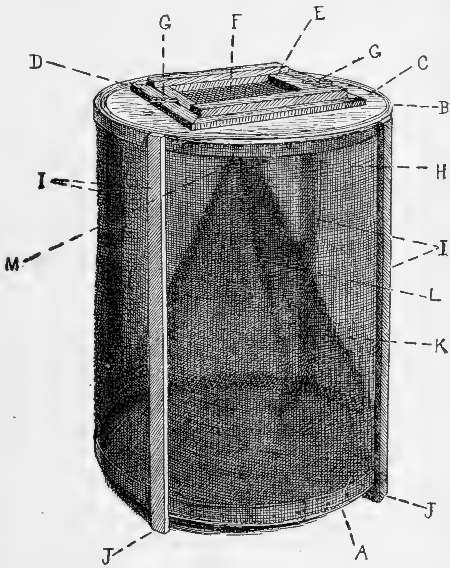

FIG. 1.—Conical hoop flytrap, side view. *A*, Hoops forming frame at bottom. *B*, Hoops forming frame at top. *C*, Top of trap made of barrel head. *D*, Strips around door. *E*, Door frame. *F*, Screen on door. *G*, Buttons holding door. *H*, Screen on outside of trap. *I*, Strips on side of trap between 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.

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 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

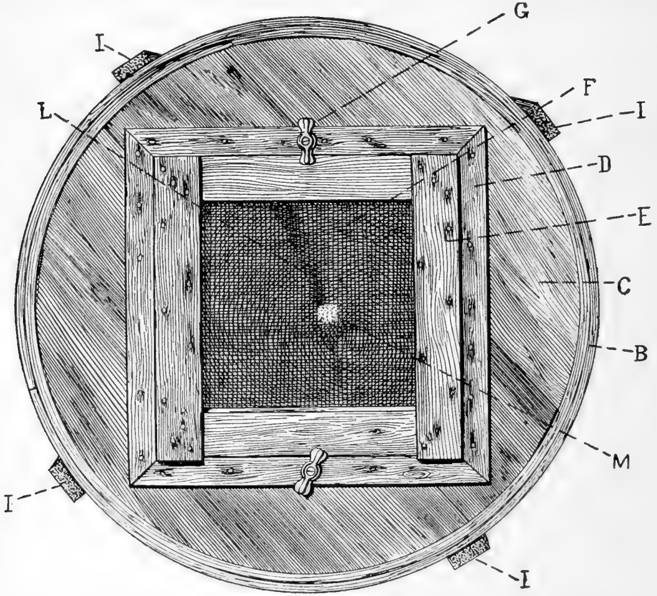

FIG. 2.—Conical hoop flytrap, top view. Letters designate parts as in figure 1.

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 project 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*), or a narrow lath may be nailed along these edges. 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*, 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,

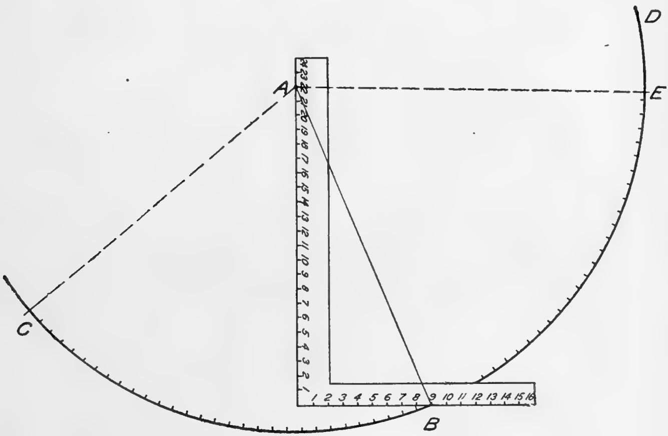

FIG. 3.—Method of laying out a pattern for the construction of a cone. Cut out on curved line *C* to *E* and on dotted lines from *A* to *C* and *A* to *E*.

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 $56\frac{1}{2}$ 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 $57\frac{1}{2}$ 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.

A modification of the previously described trap has been made by Mr. D. C. Parman of the Bureau of Entomology. The principal point of advantage in this type is that it can be made more quickly and with fewer tools. The principles and dimensions are the same, the most striking difference being the absence of a wooden top. A single hoop with the thick edge down forms the upper frame of the cylinder and the entire top is made of screen. A circular piece of screen with a diameter about 3 inches greater than the diameter of the cylinder is cut; a hoop with a diameter equal to the inside of the top of the trap is then made of heavy wire and laid upon the disk of screen and the edges of the screen bent in over it. By folding in and crimping the edges of the wire over the wire hoop it will remain in position without difficulty and the edges of the screen disk are used to lift the top of the trap out for emptying flies. It is important to have the screen top fit the inside of the cylinder very snugly at all points. If there is any space left where flies can escape it is a good plan to bind the edge of the top with a strip of burlap. This not only helps to close the openings but keeps the hoop in place and aids in removing the top. Another difference is that the screen forming the sides of the cylinder is placed on the inside of the hoops and legs, the frame being built first and then the cylinder formed by tacking the wire on the inside of the hoops and nailing in along the upright strips and against the wire short pieces of laths with their upper ends against the lower edge of the hoop forming the top of

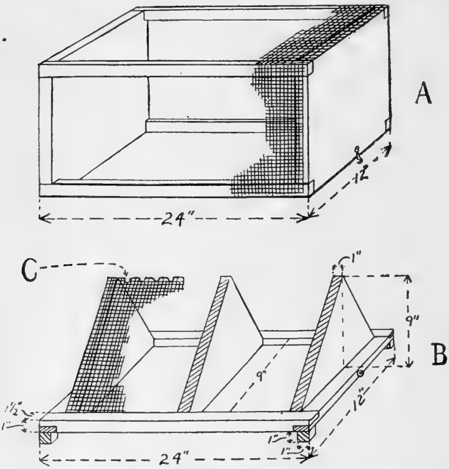

FIG. 4.—Tent flytrap. When the trap is set up the screen box, *A*, fits on the base, *B*, and two pans of bait are placed beneath the tent. *C*, Hole in screen at apex of tent.

the trap and extending downward along the legs about two-thirds of their length. These strips hold the wire in place and give rigidity to the trap, and they are thick enough to project beyond the inner surface of the hoop and form a support upon which the edges of the screen top rest.

Conical traps with steel frames are satisfactory, but they are less easily rescreened. 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.

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 the 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.

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.

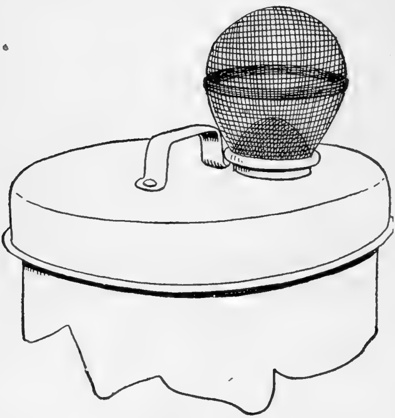

FIG. 5.—Top of garbage can with small balloon flytrap attached.

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 to cover 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 Farmers' Bulletin 851 of the Department

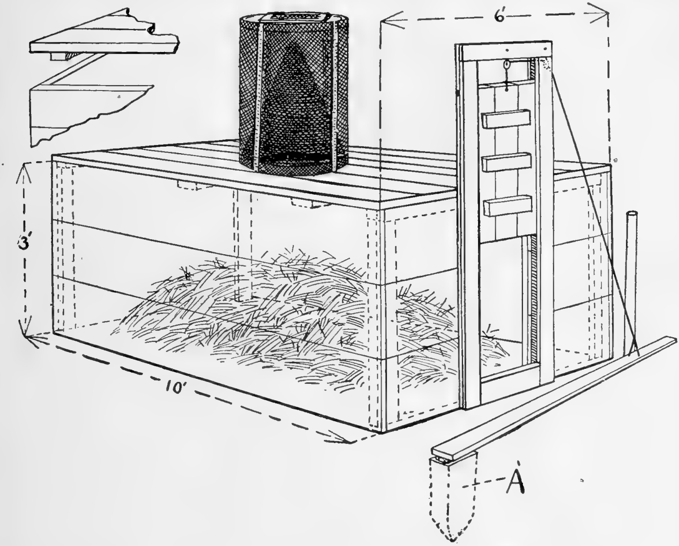

FIG. 6.—Use of flytrap in connection with manure bin. *A*, Block of wood set in ground to which lever raising door is hinged.

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 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

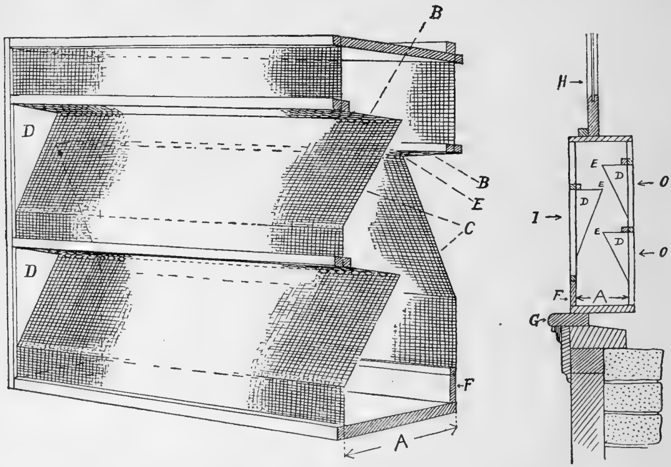

FIG. 7.—Hodge type window trap. At left, trap with end removed to show construction; at right, cross section of trap placed in a window. *A*, End of trap. *B*, Upper side of folds in screen. *C*, Lower side of folds in screen. *D*, Portion of end of trap sawed out and returned after attaching screen. *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.

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.

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. They tend to exclude the light, however, and are somewhat cumbersome, especially in thin-walled buildings.

TRAPPING THE SCREW-WORM FLY.[5]

Recent efforts to reduce the loss to the live-stock industry of the Southwest resulting from the ravages of the screw-worm have directed attention to the employment of flytraps in this work.

Mention has been made of the importance of preventing the breeding of flies as a prerequisite to effective control. This is equally true of the screw-worm and other blowflies, which attack animals, and of the house fly. In the case of these blowflies main dependence must be placed on the complete and prompt burning of all carcasses and animal refuse.

Experiments conducted in the range sections of Texas indicate that traps properly baited and set are of material aid in preventing screw-worm injury to live stock. It is advised that at least one trap be maintained on each section of land. These should be located preferably near watering places and where cattle congregate, especially in the so-called "hospital traps," where the screw-worm-infested animals are kept for treatment.

The conical-type traps as described are advised. The traps should be set on a board platform about 2 feet square, securely fastened to a tree or on a post where the trap and bait will be the least disturbed by stock or wild animals.

During the latter half of one season over 100 gallons of flies, the vast majority of which were screw-worm flies, were captured in about 25 traps operated on a ranch in west Texas.

The question of the baits best adapted for this species and other points in regard to the operation of the traps are briefly discussed under subsequent headings.

BAITS FOR TRAPS.

The problem of selecting the best bait for flies is an important one. In choosing a bait it should be remembered that it is largely the fermentation which renders the material attractive, and that baits are most attractive during their most active period of fermentation. As has been indicated, the kind of bait used should be governed by the species of flies the destruction of which is desired. This is most often the house fly.

Experiments conducted indicate that a mixture of cheap cane molasses ("black-strap") and water is among the most economical and effective baits for the house fly. One part of molasses is mixed

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[5] *Chrysomyia macellaria* Fab.

with three parts of water. The attractiveness becomes marked on the second or third day.

Sugar-beet or "stock molasses," which is very cheap, especially in regions where produced, when mixed in the foregoing proportions, is fairly attractive.

On dairy farms, probably milk is the next choice as a bait to cane-molasses solution, considering its convenience. The curd from milk, with about one-half pound of brown sugar added to each pound and water to make it thoroughly moist, is a very good bait and continues to be attractive for 10 days or more if kept moist. A mash of bran made quite thin with a mixture of equal parts of water and milk and with a few tablespoonfuls of brown sugar and cornstarch and a yeast cake added makes an attractive and lasting bait. During hot weather stirring the old bait or adding fresh is a daily necessity if best results are to be secured.

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. Honeybees are sometimes caught in large numbers at this bait. When this happens some of the other baits recommended should be used.

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 membranes which form the lining of the intestines of cattle or hogs are 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 very near habitations or materials intended for human consumption.

For use under range conditions experiments are underway with dried gut slime. This material is giving satisfaction as a screw-worm fly attractant and is easily carried, being in a highly concentrated form. The flaky material is placed in the bait pans and water added at the rate of 1 part slime to 10 or 20 parts water, after which the mixture is thoroughly stirred.

Another packing-house product known as blood tankage is a good fly bait when used with molasses and water. This combination results in the capture of a large percentage of house flies. 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 percentage of house flies in traps over such baits ranges from 45 to 75.

Overripe or fermenting fruit, such as watermelon rinds or crushed bananas, placed in the bait pans sometimes gives satisfactory results.

A combination of overripe bananas with milk is much more attractive than either one used separately. A considerable number of blowflies 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. Under range conditions it is advisable to use a more substantial bait pan and preferably one 1½ inches deep, so that a greater amount of bait may be used, thus preventing complete drying out between visits to the trap. 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. For liquid baits 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 flytrapping 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. In the operation of flytraps in controlling the screw-worm it has not been found necessary, especially during hot weather, to kill the flies, as they die very rapidly within the traps. In order to empty a trap it may be inverted and the dead flies shaken down. As the living flies will naturally go upward, the door may then be removed and the dead flies shaken out, the door replaced, and the trap set upright without loss of many of the living flies.

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 teaspoonfuls 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. Brown sugar or molasses and water with $2\frac{1}{2}$ per cent formaldehyde (commercial, 40 per cent solution) added will probably also give satisfactory results. As far as possible other liquids should be removed when poisoned baits are exposed.

The use of poison solutions, especially arsenical solution in tubs containing portions of animal carcasses, has been tried and advocated against the screw-worm by a number of stockmen. A comparatively weak poison solution—about 1 gallon of dip, diluted for use on cattle, to 7 gallons of water—is sufficient. Best results usually have been secured where a considerable portion of the animal matter was allowed to protrude from the poison solution, as there is a tendency for the solution to harden the bait and prevent its decomposition, thus reducing its attraction for flies.

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. Arsenical solutions, as is well known, are extremely poisonous to man and animals. Care should be taken to protect the poisoned baits from live stock and it is not advisable to have the baits close to barnyards where fowls are kept, as they may be poisoned by eating the dead flies.

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U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No 734

FLYTRAPS AND THEIR OPERATION

UNITED STATES DEPARTMENT OF AGRICULTURE 1862 1889

BOTH THE HOUSE FLY AND BLOWFLIES may be captured in traps, but the bait to be used will depend on which kind is prevalent, and on the location of the traps. This bulletin tells how to make the flytraps that have been found most effective, where to put them, and how to bait and care for them.

Flytrapping, of course, affords only partial relief. The logical method of fly control is to prevent the multiplication of these pests, by proper treatment of their breeding places. The reader is therefore referred to Farmers' Bulletin 1408 for further information on house-fly control, and to Farmers' Bulletin 857 for additional measures to be used against the screw-worm fly and certain other blowflies injurious to livestock.

Washington, D. C. Issued June 10, 1916; revised July, 1925

FLYTRAPS AND THEIR OPERATION

F. C. Bishopp, *Entomologist, Investigations of Insects Affecting the Health of Animals, Bureau of Entomology*

CONTENTS

USES AND LIMITATIONS OF FLYTRAPS

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.

It may be said that there are two main ways in which flytraps are valuable: (1) By catching flies which come to clean premises from other places which are insanitary and (2) by 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.

Flytrapping should begin early in the 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, including the screw-worm fly;[1] and (2) those which breed in vegetable as well as in animal matter. In the latter group the house fly[2] 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 in rare cases may contaminate foodstuffs. The stable fly,[3] which breeds in

[1] *Chrysomya macellaria* Fab. [2] *Musca domestica* L. [3] *Stomoxys calcitrans* L.

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cow manure or decaying vegetable matter, and the horn fly,[4] which breeds in 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.

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 that 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 Professor 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.

There are now being made by certain firms in the Southwest traps of the dimensions and with the desirable features discussed in the following pages. These traps are all metal and some are built so that they can be taken apart for shipment.

THE CONICAL HOOP TRAP

A trap which appears from extensive tests made by E. W. Laake and the writer to be best for effective trapping, durability, ease of construction and repair, and cheapness may be made as follows:

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[4] *Haematobia irritans* L.

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 $1. 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 80 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.

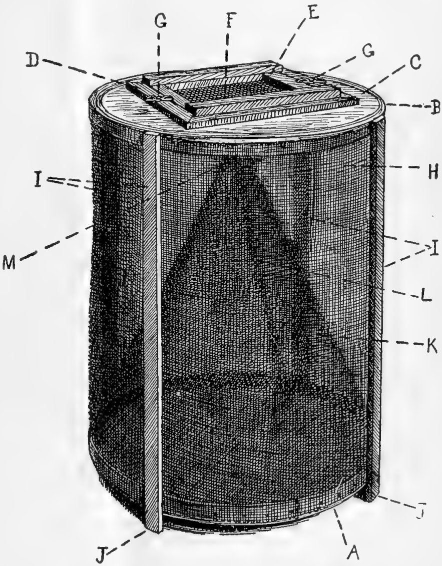

Fig. 1.—Conical hoop flytrap, side view. *A*, hoops forming frame at bottom. *B*, Hoops forming frame at top. *C*, Top of trap made of barrel head. *D*, Strips around door. *E*, Door frame. *F*, Screen on door. *G*, Buttons holding door. *H*, Screen on outside of trap. *I*, Strips on side of trap between 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

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 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 project 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*), or a narrow lath may be nailed along these edges. 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.

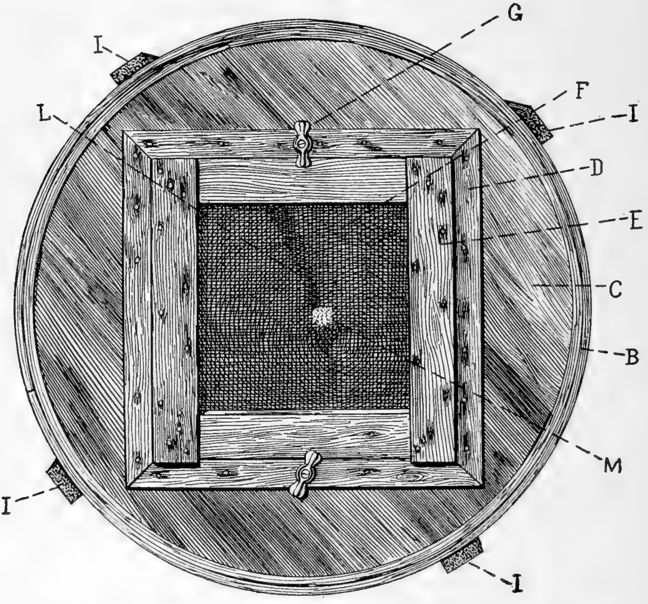

FIG. 2.—Conical hoop flytrap, top view. Letters designate parts as in Figure 1

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 of on the other leg at *B*, 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 $3\frac{1}{7}$.

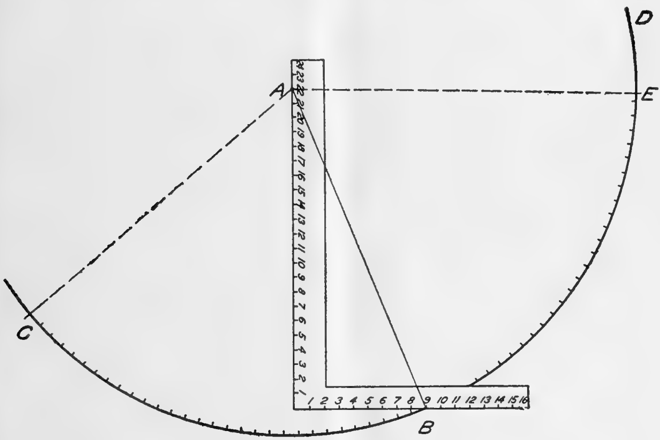

FIG. 3.—Method of laying out a pattern for the construction of a cone. Cut out on curved line from C to E and on dotted lines from A to C and A to E

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 is of importance in securing the greatest efficiency.

OTHER FORMS OF CONICAL TRAPS

A modification of the previously described trap has been made by D. C. Parman of the Bureau of Entomology. The principal point of advantage in this type is that it can be made more quickly and with fewer tools. The principles and dimensions are the same, the most striking difference being the absence of a wooden top. A single hoop with the thick edge down forms the upper frame of the cylinder and the entire top is made of screen. A circular piece of screen with a diameter about 3 inches greater than the diameter of the cylinder is cut; a hoop with a diameter equal to the inside of the top of the trap is then made of heavy wire and laid upon the disk of screen and the edges of the screen bent in over it.

By folding in and crimping the edges of the wire over the wire hoop it will remain in position without difficulty and the edges of the screen disk are used to lift the top of the trap out for emptying flies. It is important to have the screen top fit the inside of the cylinder very snugly at all points. If there is any space left where flies can escape it is a good plan to bind the edge of the top with a strip of burlap. This not only helps to close the openings but keeps the hoop in place and aids in removing the top. Another difference is that the screen forming the sides of the cylinder is placed on the inside of the hoops and legs, the frame being built first and then the cylinder formed by tacking the wire on the inside of the hoops and nailing in along the upright strips and against the wire short pieces of laths with their upper ends against the lower edge of the hoop forming the top of the trap and extending downward along the legs about two-thirds of their length. These strips hold the wire in place and give rigidity to the trap, and they are thick enough to project beyond the inner surface of the hoop and form a support upon which the edges of the screen top rest.

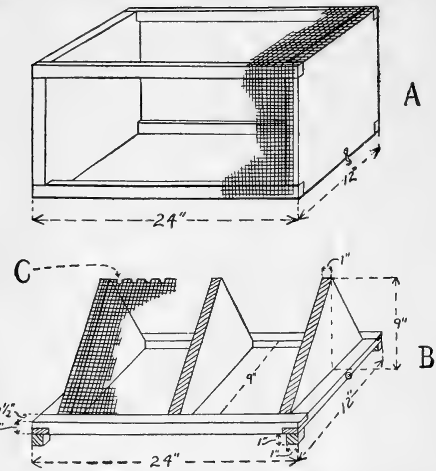

FIG. 4.—Tent flytrap. When the trap is set up the screen box, *A*, fits in the base, *B*, and two pans of bait are placed beneath the tent. *C*, Hole in screen at apex of tent

Conical traps with steel frames are satisfactory, but they are less easily rescreened. 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.

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.

ALL-METAL FLYTRAP

There is some demand for flytraps made of more durable material than those that have been described on foregoing pages. For the guidance of those who desire such traps the following directions, together with a working drawing (fig. 5), are given:

SPECIFICATIONS

Dimensions—As per working drawing.

Wire—14-mesh galvanized or copper gauze.

Cyinder—Wire gauze, to be soldered completely around inside of top ring and at intervals of 2 inches or less in groove of bottom ring. Vertical seam to be soldered entire and placed behind one leg. Where shipment of traps is not contemplated the diameter of the top of the cylinder may be the same as that of the bottom.

Top—Wire gauze to be soldered completely around periphery on inside of top ring.

Cone—Wire gauze to be soldered completely around inside of cone ring and vertically along seam. A 1-inch inlet hole shall be formed at apex of cone.

Frame—To be made of 24-gauge galvanized iron. This includes top and bottom rings and legs.

Legs—Galvanized iron channels made as per detailed drawing and secured to top and bottom rings with four rivets, ⅛-inch in diameter, to each leg. First turned and drilled as per drawing.

Bottom cylinder ring—J shaped, with bottom edge of cylinder dropped into J—crimped and soldered to secure. Ends of ring riveted to secure.

Cone ring—Galvanized iron band with $\frac{3}{16}$-inch round iron wire rolled into lower edge as per cross-section drawing of "cone ring."

Wing nuts—Four copper wing bolts and nuts, as per drawing, to hold cone securely in place.

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 the eyes on the base (*B*). Small blocks 1 inch thick are nailed beneath the corners of the tent frame to serve as legs.

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. 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.

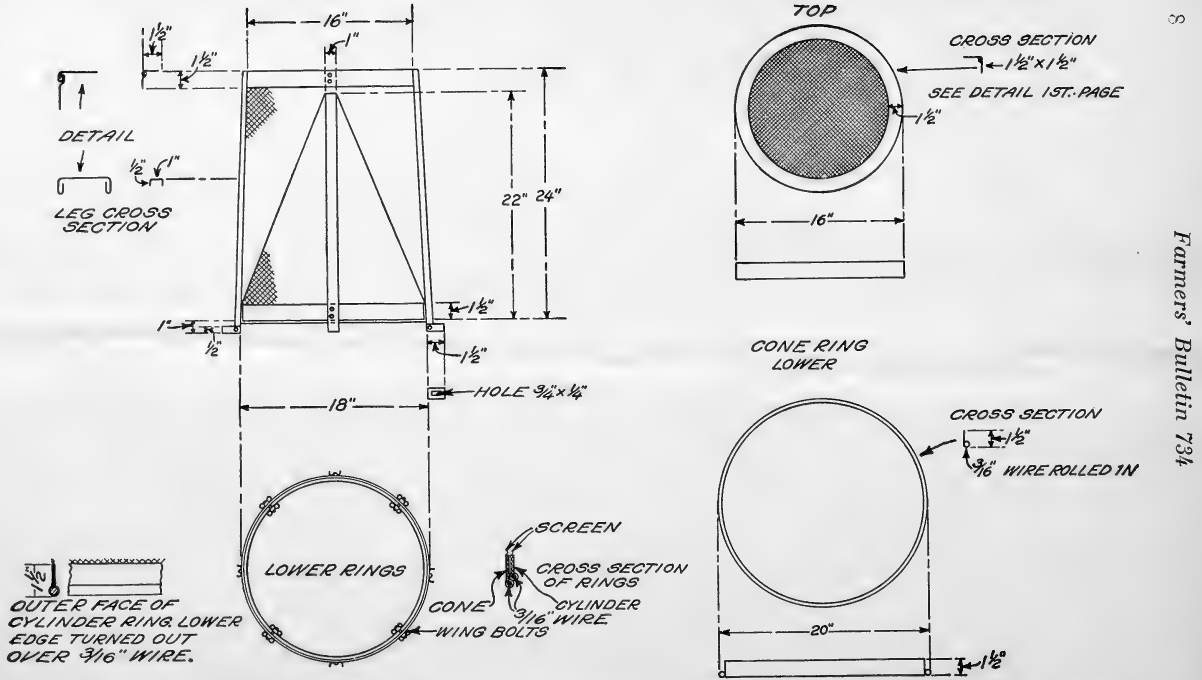

Fig. 5.—Working drawings of all-metal flytrap. The cones are removable and traps and cones can be telescoped for shipment. The diameter of the trap may be made the same at the top and bottom if traps are not to be shipped

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 to cover 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

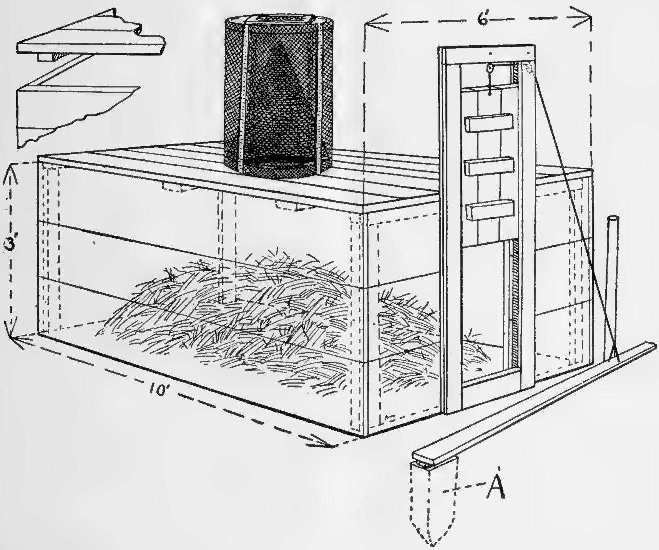

FIG. 6.—Use of flytrap in connection with manure bin. *A*, Block of wood set in ground to which lever raising door is hinged

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 R. H. Hutchison, as described in Farmers' Bulletin 851 of the Department of Agriculture. Where large quantities of manure are produced on a farm

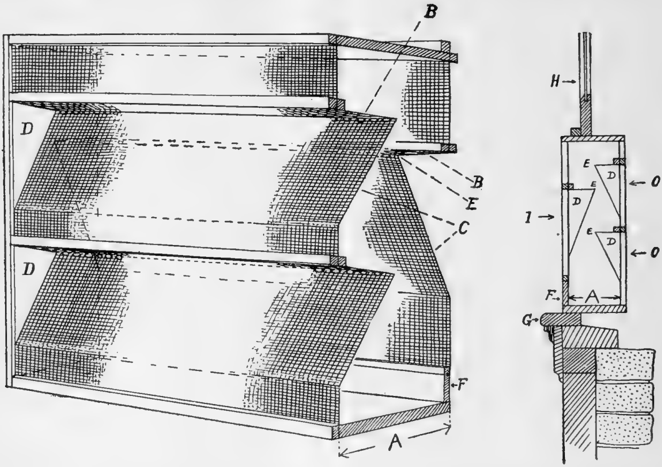

FIG. 7.—Hodge type window trap. At left, trap with end removed to show construction; at right, cross section of trap placed in a window. *A*, End of trap. *B*, Upper side of folds in screen. *C*, Lower side of folds in screen. *D*, Portion of end of trap sawed out and returned after attaching screen. *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

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 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.

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. They tend to exclude the light, however, and are somewhat cumbersome, especially in thin-walled buildings.

TRAPPING THE SCREW-WORM FLY[5]

Recent efforts to reduce the loss to the livestock industry of the Southwest resulting from the ravages of the screw-worm have directed attention to the employment of flytraps in this work.

Mention has been made of the importance of preventing the breeding of flies as a prerequisite to effective control. This is equally true of the screw-worm and other blowflies, which attack animals, and of the house fly. In the case of these blowflies main dependence must be placed on the complete and prompt burning of all carcasses and animal refuse.

Experiments conducted in the range sections of Texas indicate that traps properly baited and set are of material aid in preventing screw-worm injury to livestock. It is advised that at least one trap be maintained on each section of land. These should be located preferably near watering places and where cattle congregate, especially in the so-called hospital traps, where the screw-worm-infested animals are kept for treatment.

The conical-type traps as described are advised. The traps should be set on a board platform about 2 feet square, securely fastened to a tree or on a post where the trap and bait will be the least disturbed by stock or wild animals.

During the latter half of one season over 100 gallons of flies, the vast majority of which were screw-worm flies, were captured in about 25 traps operated on a ranch in west Texas.

The question of the baits best adapted for this species and other points in regard to the operation of the traps are briefly discussed under subsequent headings.

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[5] *Chrysomya macellaria* Fab.

BAITS FOR TRAPS

The problem of selecting the best bait for flies is an important one. In choosing a bait it should be remembered that it is largely the fermentation which renders the material attractive, and that baits are most attractive during their most active period of fermentation. As has been indicated, the kind of bait used should be governed by the species of flies the destruction of which is desired. This is most often the house fly.

HOUSE-FLY BAITS

A mixture of cheap cane molasses ("blackstrap") and water is one of the most economical and effective baits for the house fly. One part molasses is mixed with three parts water. The attractiveness becomes marked on the second or third day.

Sugar-beet or "stock molasses," which is very cheap in regions where produced, when mixed in the foregoing proportions is fairly attractive.

Sirup made by dissolving one part of ordinary brown sugar in four parts of water and allowing the mixture to stand a day or two to induce fermentation is almost equal to 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. Honeybees are sometimes caught in large numbers with this bait. When this happens some of the other baits recommended should be used. On dairy farms probably milk is next choice as a bait to cane-molasses solution, considering its convenience. The curd from milk, with about one-half pound of brown sugar added to each pound, and water to make it thoroughly moist, is a very good bait and continues to be attractive for 10 days or longer if kept moist. A mash of bran made quite thin with a mixture of equal parts of water and milk and with a few tablespoonfuls of brown sugar and cornstarch and a yeast cake added makes an attractive and lasting bait.

The foregoing baits are rendered more attractive by stirring occasionally.

BLOWFLY BAITS FOR USE AROUND MARKETS, ETC.

With the baits before mentioned 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 membranes which form the lining of the intestines of cattle or hogs are 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 around habitations or materials intended for human consumption.

At the front of and at loading docks of meat-packing establishments where house flies are troublesome and blowflies are usually not abundant it is best to bait the traps with one of the house-fly baits listed above. Around meat markets where both house flies and blowflies abound one of the combination baits given on page 13 should be employed.

BAITS FOR SCREW-WORMS AND BLOWFLIES UNDER RANGE CONDITIONS

Where rabbits or other wild animals are plentiful they make a very satisfactory bait for use on the ranges; in fact, they are rather better than any other available bait. The animal should be opened up so as to expose the intestines; and when the weather is very dry it is best to keep some water in the pan, as it adds to the attractiveness of the bait. Entrails and other animal refuse may be utilized in a similar way when they are available.

The main objection to the use of this type of bait is that some maggots are likely to complete their growth and escape from the bait pans. This can be largely avoided by using borax solution in the bait pan in place of the water—1 ounce of powdered borax to each gallon of water. This does not check the decomposition enough to reduce greatly the attractiveness of the bait and practically prohibits the escape of any maggots

As a substitute for wild animals or animal refuse when they are not available, experiments show that fairly satisfactory catches can be secured by utilizing dried "gut slime" or dried whole egg. The former is not generally on the market but can be prepared by packing houses at a moderate cost. Both of these materials are easily carried on a saddle horse and all that is necessary is to place about one-fourth pound in the bait pan and add 2 quarts of water, after which the mixture should be stirred. The more frequently any of these baits is agitated, the greater the catch which will be secured. If the bait is kept well moistened it will continue attractive for 10 days or longer. Our experiments indicate that where these baits are made alkaline by the addition of a teaspoonful of washing or baking soda they are made more attractive, especially during the first week.

COMBINATION BAITS

With a number of the baits before mentioned both house flies and blowflies are captured. This is especialy true with the "gut slime" and dried egg. Where both of these kinds of flies are abundant such baits are desirable. Certain other mixtures may also be utilized. A packing-house product known as blood tankage is a good fly bait when used with molasses and water. Fish scraps or meat scraps, especially with molasses and water added, will attract all kinds of flies. Overripe or fermenting fruit such as watermelon rinds or crushed bananas often gives very satisfactory results. A combination of overripe bananas with milk is much more attractive than either one used separately.

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 a 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. Under range conditions it is advisable to use a more substantial bait pan and preferably one 1½ inches deep, so that a greater amount of bait may be used, thus preventing complete drying out between visits to the trap. 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. For liquid baits 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 flytrapping 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. In the operation of flytraps in controlling the screw-worm it has not been found necessary, especially during hot weather, to kill the flies, as they die very rapidly within the traps. In order to empty a trap it may be inverted and the dead flies shaken down. As the living flies will naturally go upward, the door may then be removed and the dead flies shaken out, the door replaced, and the trap set upright without loss of many of the living flies.

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.

Doctor 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."

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.

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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.

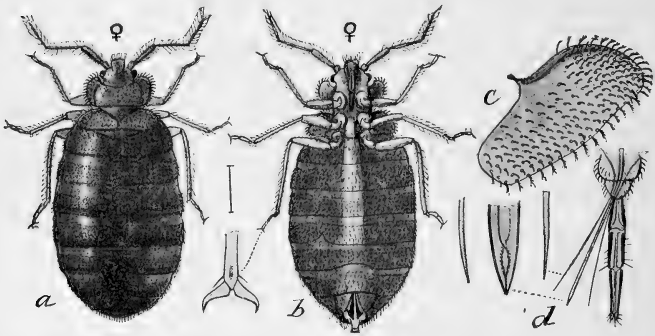

FIG. 1.—Bedbug (*Cimex lectularius*): *a*, Adult female, engorged with blood; *b*, same from below; *c*, rudimentary wing pad; *d*, mouth parts. *a, b*, Much enlarged; *c, d*, highly magnified. (Author's illustration.)

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*) *Oeciacus 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.

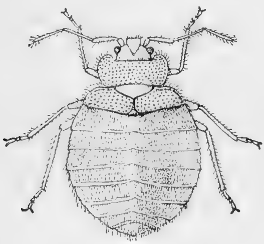

FIG. 2.—Bedbug: Adult before engorgement. Much enlarged. (Author's illustration.)

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).

[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

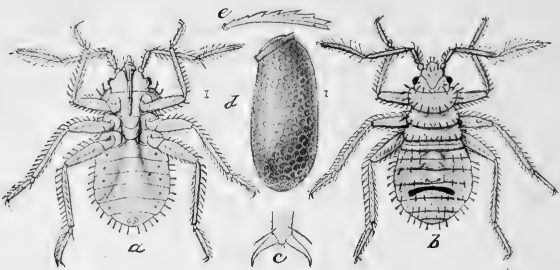

FIG. 3.—Bedbug: Egg and newly hatched larva: *a*, Larva from below; *b*, larva from above; *c*, claw; *d*, egg; *e*, hair or spine of larva. Greatly enlarged, natural size of larva and egg indicated by hair lines. (Author's illustration.)

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

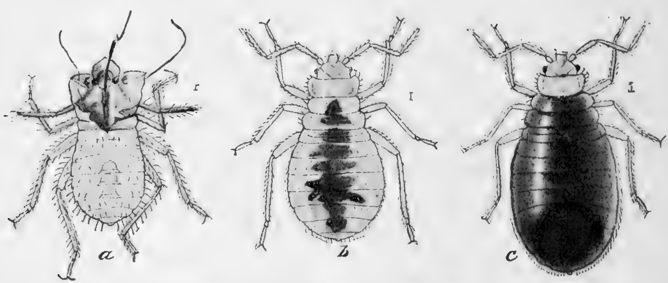

FIG. 4.—Bedbug: *a*, Larval skin shed at first molt; *b*, second larval stage immediately after emerging from *a*; *c*, same after first meal, distended with blood. Greatly enlarged. (Author's illustration.)

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

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[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

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[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.

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THE BEDBUG

C. L. MARLATT

Entomologist and Assistant Chief

FARMERS' BULLETIN 754

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C. Issued October 14, 1916; revised January, 1918

Show this bulletin to a neighbor. Additional copies may be obtained free from the Division of Publications, United States Department of Agriculture

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A STRENUOUS STRUGGLE, a vigorous campaign, is before any housewife who is called upon to dispute the occupancy of her home with that persistent pest unfavorably known as the bedbug, who, gorged with the blood of his victim, lieth up in his lair from daylight to candle light, only to swoop down upon his helpless sleeping prey during the midnight watches.

Even a flood of gas or electric light will not protect the human host, for the stress of hunger will cause the bedbug to emerge from its place of concealment in a well-lighted room at night, and even attack, voraciously, in broad daylight, if long without food.

Certain natural enemies of this pest are to be found in our homes, but they are almost as unwelcome to the housewife as the bedbug itself, and, besides, furnish little, if any, effective control.

There are remedies—many of the most effective of which are the old-fashioned household remedies, some are preparations recently put on the market by their manufacturers, while others are fumigants, requiring more than common care and more than ordinary intelligence in their use, as the gases are deadly poisons.

This bulletin tells all about them—but the main factor of success is eternal vigilance.

THE BEDBUG[1]

CONTENTS.

ITS PRESENCE EXPLAINED.

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.

Nevertheless, the presence of the bedbug in houses, both from the standpoint of personal comfort and the possible carriage of disease, is not to be lightly considered, and the failure on the part of anyone to institute immediate efforts of eradication will warrant the odium which is properly attached to "buggy" premises. The most important purpose of this bulletin is, in addition to giving a general account of this house pest, to indicate effective means by which it can be eradicated promptly.

[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.

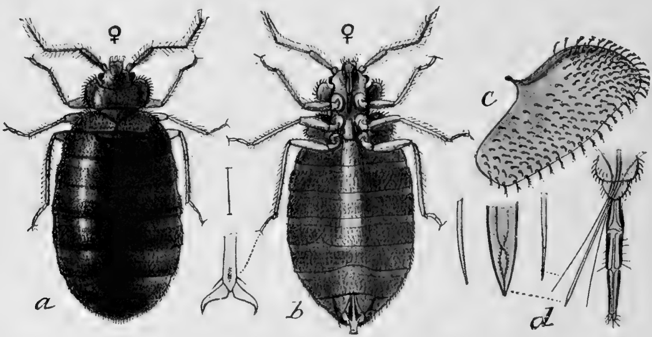

FIG. 1.—Bedbug (*Cimex lectularius*): *a*, Adult female, engorged with blood; *b*, same from below; *c*, rudimentary wing pad; *d*, mouth parts. *a*, *b*, Much enlarged; *c*, *d*, highly magnified. (Author's illustration.)

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*) *Oeciacus 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.

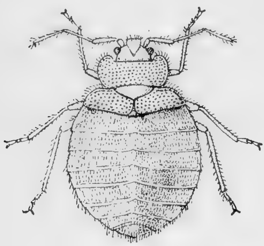

FIG. 2.—Bedbug: Adult before engorgement. Much enlarged. (Author's illustration.)

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).

[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

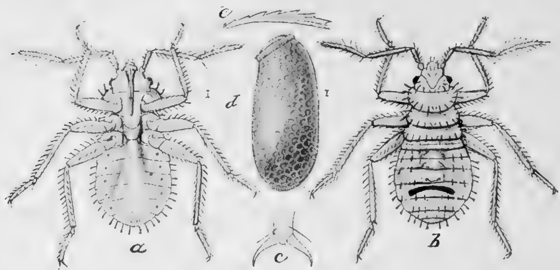

FIG. 3.—Bedbug: Egg and newly hatched larva: *a*, Larva from below; *b*, larva from above; *c*, claw; *d*, egg; *e*, hair or spine of larva. Greatly enlarged, natural size of larva and egg indicated by hair lines. (Author's illustration.)

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

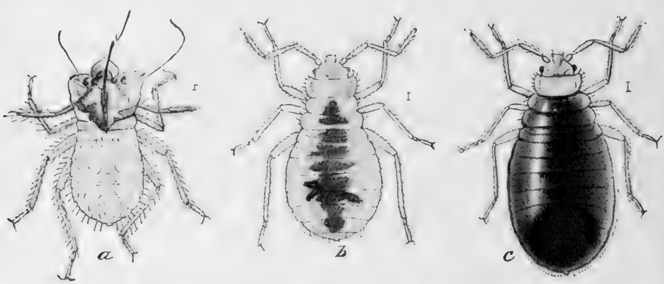

FIG. 4.—Bedbug: *a*, Larval skin shed at first molt; *b*, second larval stage immediately after emerging from *a*; *c*, same after first meal, distended with blood. Greatly enlarged. (Author's illustration.)

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

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[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.

[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.

Temperature control.—The possibility of temperature control is indicated in the discussion elsewhere of the effect of temperature on this insect. A temperature maintained below freezing for 10 or 15 days destroys the eggs, and this temperature continued for 15 days to a month will destroy the newly hatched young. It may be, therefore, that if infested houses in cold climates should be opened up and allowed to remain at a temperature well below freez-

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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.

ing for a considerable period, all eggs and the young, and possibly most if not all of the adults, would be exterminated. This method of control might perhaps be practicable at least in the case of summer houses in the north which are left untenanted in the winter.

The maintaining of high temperatures may be an even more efficient method of control. The activity of the bedbug is at its greatest between 60° and 70° to 75°. As indicated elsewhere, in a temperature of 96° to 100° F., accompanied with a high degree of humidity, newly hatched bedbugs perish within a few days, and, if this temperature is raised to 113° F., in a few minutes. A temperature of 113° will also destroy the eggs, and with these higher temperatures the item of humidity is not apparently important.

A very practical test of this method of control was made in Ontario, Canada, by the Dominion Entomological Department,[1] adapting the method of control of insects infesting granaries and flour mills by superheating. In this instance an eight-room, two-story frame house, badly infested with bedbugs, was during the month of July brought to a very high degree of heat by making up good fires in the heating furnace and other stoves in the house and closing up the house to retain the heat. Recording thermometers placed in different rooms indicated a gradual rise of temperature from 77° to 160° during the period from 9.30 in the morning to 7.30 in the evening, the outside temperatures during the same period ranging from 64° to 73° F. At 1.30, when the temperature in the different rooms ranged from 109° to 130°, many adults and immature forms had already succumbed. By 4.30 the temperature was ranging from 127° to 148° in different rooms, and all the insects were dead. The continuation of the experiment was on the supposition that it would probably require a higher degree of temperature to destroy the eggs. The eradication of the bedbug from this house was complete, and no damage was done to the house or its contents. That the temperatures ranged much higher than was necessary is indicated by the temperature experiments referred to elsewhere, which indicated that the eggs as well as larvæ are destroyed within a few minutes at a temperature of 113° F. The latter temperature was also sufficient to destroy quickly the adults of fleas, cockroaches, and other insects. It would seem, therefore, that superheating of houses in midsummer to a temperature of 120° to 130° F. may prove to be one of the simplest and most effective means of eradication of this and perhaps other household pests.

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[1] Ross, W. A. Eradication of the Bedbug by Superheating. *In* Canadian Entomologist, vol. 48, No. 3, pp. 74–76. 1916.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING TO HOUSEHOLD INSECTS.

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Argentine Ant. (Entomology Bulletin 122.) 1913. Price, 25 cents.

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POWDER-POST DAMAGE BY LYCTUS BEETLES TO SEASONED HARDWOOD

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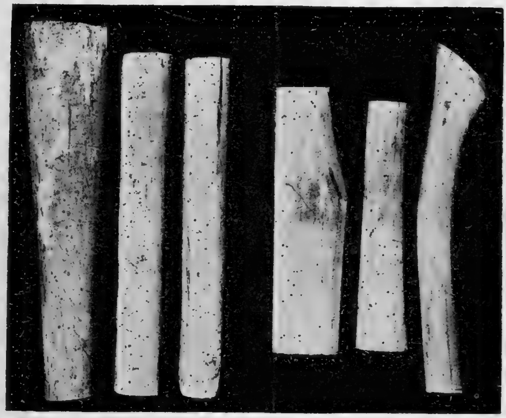

FARMERS' BULLETIN 778
UNITED STATES DEPARTMENT OF AGRICULTURE

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

Washington, D. C. January, 1917.

POWDER-POST BEETLES often ruin stored hardwoods of the finest quality by turning them into a flourlike powder. They work in whitewood or sapwood, especially second-growth hickory, ash, and oak, which has been stored or piled in one place for two or three years or longer.

Sapwood seasoned for less than eight or ten months will not be attacked, and ***heartwood is never attacked.***

In the manufacture of hickory implement handles, when feasible substitute heartwood for sapwood. See footnote 2, page 15.

By the adoption of the following system of inspection, classification, and the proper disposal of the seasoned sapwood of hardwood stock, loss by powder-post beetles can be prevented:

> Inspect material in yards and storehouses annually, preferably in November and February, and sort out and burn material showing evidence of powder post. Burn all refuse and useless sapwood material.
>
> Classify seasoned hardwood stock into (a) hickory, ash, oak, etc.; (b) heartwood, pure sapwood, and part sapwood; and (c) according to the number of years seasoned.
>
> Utilize or sell oldest stock first.
>
> Inspect all new stock to prevent introduction of powder-posted material.
>
> Use only heartwood piling sticks in lumber piles.
>
> To prevent attack treat the more valuable material, between October and March, with boiled linseed oil. Varnish or paraffin the sapwood portions of backs and interior surfaces of cabinet work, inside finish, and furniture.

Material once attacked is usually damaged beyond repair. If the injury is not too far advanced further damage can be stopped by saturating the wood with kerosene.

While there are a number of effective chemical treatments to prevent attack, and to kill the insects in the wood, the great objection to all of them is the great and recurring expense of treating material that never would be attacked if, by the proper methods of management, the premises were kept free from the pest.

POWDER-POST DAMAGE BY LYCTUS BEETLES[1] TO SEASONED HARDWOOD.

CONTENTS.

The sapwood of seasoned hardwood material of all kinds, both finished and unfinished, especially of hickory, ash, and oak, is often ruined by yellowish-white grubs from one-eighth to one-fifth inch in length which burrow through the solid wood in all directions and convert it into powder. These grubs are the young, or larvæ, of small, slender, somewhat flattened, reddish-brown to nearly black beetles, known as powder-post beetles. Wood that has been seasoned a year or longer is especially liable to this peculiar type of insect injury, which sometimes amounts to from 10 to 50 per cent of neglected material in storage. Powder-post damage by these beetles is widely distributed over the world and the consequent losses have been severe.

Under the general class of powder-post injury the work of insects representing several species and groups of species of beetles may be found, but by far the larger part and the most serious damage and losses are caused by different species of Lyctus.

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[1] The Lyctus beetles which are responsible for the principal losses belong to four species, viz, *Lyctus linearis* Goeze, *L. planicollis* Le Conte, *L. parallelopipedus* Melsheimer, and *L. cavicollis* Le Conte. These are discussed separately on pages 12–15.

NOTE.—Systems of control which adapt certain features in business management to the habits and seasonal history of Lyctus powder-post beetles have been perfected by the Bureau of Entomology and have been adopted by many manufacturers and dealers in seasoned hardwood products, and there has been a marked decrease in powder-post losses since 1906. The object of this bulletin is to describe the methods which have been found effective in preventing these losses and to induce a more general adoption of them throughout the United States as well as to show the character and extent of the damage.

EVIDENCE OF ATTACK AND CHARACTER OF POWDER-POST INJURY.

Infested wood may be detected by the fine, flourlike powder found on or beneath piled or stored hickory, ash, oak, and other seasoned hardwood products. During the first year of infestation the powder comes from exceedingly minute holes in the wood, but after the second year the small holes from which the beetles have emerged are more or less conspicuous, and from these the powder will fall when the infested material is moved or jarred. When the wood is cut or split the interior is often found converted into a mass of closely packed powdery material which has been held together by an outer thin shell and intervening fibers of sound wood. The grubs, burrowing through the solid wood in all directions, have pulverized the wood fiber and have packed their burrows with this powdered wood. The injury by Lyctus beetles is always confined to the white wood or sapwood, although the heartwood is sometimes penetrated when the matured beetles are emerging from the wood.

CLASSES OF FOREST PRODUCTS DAMAGED.

A great variety of seasoned hardwood products is subject to powder-post damage, especially hickory, ash, and oak woodwork of farming machinery and implement handles (see illustration on title-page, and figs. 1, 2, and 3); ladder stock, as rungs, etc.; and vehicle stock, as hubs, spokes, felloes, rims, singletrees, poles and shafts. Other products affected include woodwork of electric street cars; shipbuilding lumber (fig. 4); the Army and Navy stores of handles, tent poles, wheelbarrows, oars, and many other hardwood articles; interior finish or trim and ornamental woodwork, as panels, mantels, doors, doorposts, staircases, wainscoting, flooring, etc.; construction timber, including beams, joists, roof framing, etc.; furniture, including tables, chairs, bureaus, cabinets, refrigerators (before use), filing cases (fig. 5), piano stock, bookcases, cabinet-work, etc.; inside rustic work; wood specimens and curios in museums; cooperage stock (barrel-stave bolts); shoe-last blocks; walking sticks, umbrella handles, measuring rules, and blocks to be converted into golf-stick heads; fish-net hoops; ornamental bamboo (fig. 6); Japanese fans; shuttle blocks, and "picker" sticks (for driving shuttles in looms), etc.

Hickory, ash, and oak are the kinds of wood most liable to injury, but persimmon, osage orange, black walnut, butternut, maple, elm, wild cherry, locust, poplar, sycamore, eucalyptus, sassafras, orange wood, fig, bamboo, and other woods are also attacked.

FIG. 1.—Powder-posted ash shovel handle, showing exit holes of adult beetles; the work of *Lyctus planicollis*. (Original.)

FIG. 2.—Powder-posted ash shovel handle with surface wood cut away to show burrows of larvæ within; work of *Lyctus planicollis*. (Snyder.)

EXTENT OF LOSSES AND THOSE UPON WHOM THEY FALL.

Powder-post causes a loss which falls alike on the dealer, the manufacturer or owner, and the consumer of finished products. The producer of the unseasoned or crude product is not affected, because it is only after the wood is seasoned a year or more that it is attacked and damaged by these insects. Second-growth sapwood of the best

Fig. 3.—Powder-posted hickory pickax handles, showing exit holes of adult beetles; work of *Lyctus linearis*. (Original.)

quality is particularly liable to attack and serious injury, especially when it has been stored or piled in one place for two or three years or more.

The loss to seasoned hardwood products ranges from 1 to 50 per cent, sometimes representing thousands of dollars to a single manufacturer or dealer who neglects to adopt the proper preventive measures. The affected articles are not only reduced in value, but frequently are rendered worthless for the purposes for which they are intended. In the aggregate the direct financial loss that has been caused by these beetles in this country has amounted to hundreds of thousands of dollars annually. The loss increases with the length of time the infested stock is held in storage. In certain cases powder-post injury may be a menace to human life as in the weakened wood material of vehicles, ladders, etc.

CHARACTER OF THE INSECTS WHICH CAUSE THE DAMAGE.

The Lyctus beetles are small, slender, somewhat flattened, brownish to nearly black beetles, which, upon emerging from the wood where

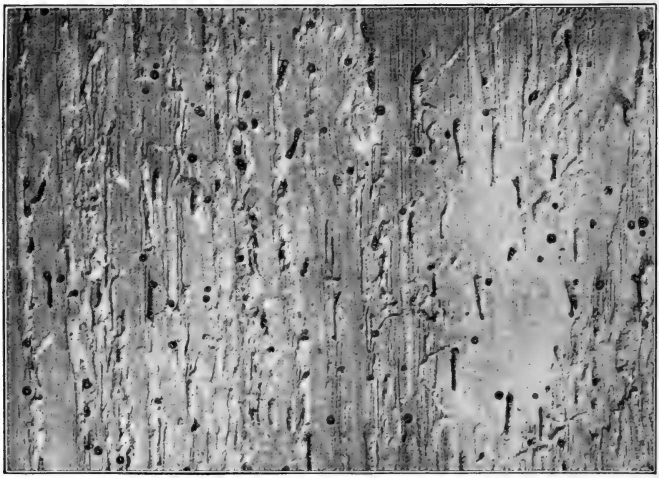

FIG. 4.—Powder-posted white ash shipbuilding lumber, showing burrows of larvæ and exit holes of adult beetles; board from closely piled stack of lumber throughout which larvæ had burrowed; work of *Lyctus planicollis*. (Original.)

they breed and pass the winter as larvæ, fly or crawl about in search of suitable wood material in which to deposit their eggs.

HABITS AND SEASONAL HISTORY OF LYCTUS BEETLES.

There are four stages in the life history of these insects—namely, the egg, the larva or grub, the pupa or resting stage, and finally the adult or beetle.

The egg (fig. 7) is deposited in the pores of the wood by the female beetle soon after it emerges from the wood. The minute larva which hatches from the egg proceeds to burrow in and through the wood in all directions, feeding and growing as it proceeds, until it has attained its full size. The full-grown larva (fig. 8) is a yellowish-white grub ranging in length from one-eighth to one-fifth of an inch, with three pairs of legs, and with the tip of the body curved under toward the head. Upon reaching maturity as a larva it excavates a cell at the end of its burrow (fig. 9), and in this transforms to the pupa (fig. 10). Later the pupa changes to the adult beetle (fig. 11), which can fly in search of suitable places to lay its eggs.

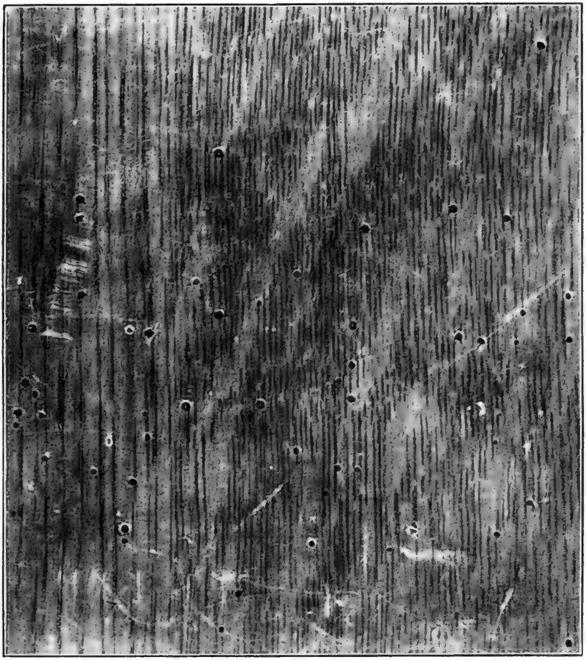

FIG. 5.—Powder-posted oak file case, showing exit holes of adult beetles; work of *Lyctus planicollis*. (Original.)

Seasoned wood is attacked by these beetles because the chemical changes which take place in the process of seasoning render the nutritive substances in the wood, such as sugar and starch, especially suitable as food for the development of the young or larval stage.

Each female beetle deposits many eggs,[1] and many females oviposit in a single piece of wood, so that the combined work of their nu-

[1] A large female of *Lyctus planicollis* Lec., about one-fourth inch in length, that was dissected contained ovaries as two separate, elongate ovate clusters one-tenth inch in length, one of which was about one-third the size of the other. These ovaries took up most of the space of the abdomen. The eggs were arranged in rows so as to have the appearance of being braided. The mature ovules, or fully formed eggs, are pointed at one end and rounded at the other, with the rudimentary strand present at the rounded end. The egg surface is apparently granular. At least 40 eggs were in the larger mass.

merous progeny, burrowing through the wood in quest of food for their development, results in the complete destruction of the interior wood fiber and its conversion into a mass of fine powder. If the first attack and the first generation do not accomplish this destruction, subsequent generations will follow in the same wood until nothing of the solid fiber is left but a thin outer shell.

FIG. 6.—Powder-posted ornamental section of bamboo, showing exterior and interior of split bamboo; work of *Lyctus parallelopipedus*. (Original.)

The different kinds of Lyctus beetles vary somewhat in their habits and seasonal history, but there is a general similarity. They pass the winter as larvæ in the wood, change to pupæ in the early spring, and during late spring and early summer the adult beetles emerge from the wood and fly about. Under natural out-of-door conditions the eggs are laid in the pores of the wood soon after activity commences in the spring, but in storehouses, sheds, or buildings kept warm and dry, the development may take place and the eggs may be deposited much earlier.

The larvæ remain dormant or active in the wood, according to the temperature of the place where stored, and in consequence infestation in wood stored in cold places may pass unnoticed. If the wood is re-

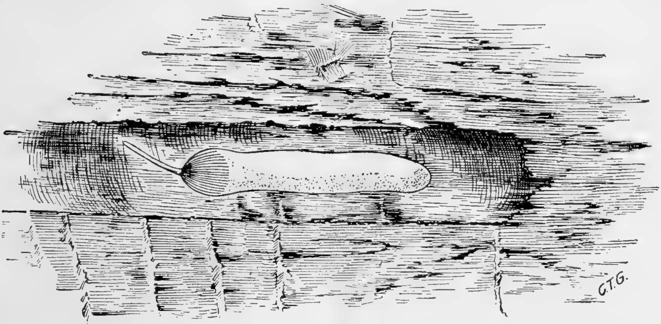

FIG. 7.—Egg of a powder-post beetle, *Lyctus planicollis,* in pore of wood on radial section of ash ladder-rung stock; pore opened to show egg. Highly magnified. (Snyder.)

moved from outdoors, open storage sheds, or other places which are cold in winter, to the dry kiln, the dormant larvæ start to work in the wood, as shown by the ejection of boring dust or powder. Handling or jarring infested wood appears temporarily to stop the activity of larvæ contained in it.

FIG. 8.—Larva of a powder-post beetle, *Lyctus planicollis.* Enlarged. (Chittenden.)

In general, the adults or beetles are active between the first of March and the last of July at Washington, D. C. (about latitude 39° and longitude 77°, and practically at sea level), but the period varies according to the species, the temperature of the storerooms, and the geographical location. According to the senior author, the variation due to latitude, longitude, and altitude from a date at Washington, D. C., will be approximately four days for each degree of latitude, 5° of longitude, and 400 feet of altitude, being earlier in the season southward, westward, and descending. The number of adult beetles that might be active and deposit eggs after the last of July at Washington, D. C., is so insignificant that practically no damage is done by them. Therefore the danger of attack would be over relatively earlier at parts south of Washington and westward, and later northward. The approximate dates of flying and egg laying by each species under outdoor conditions at Washington, D. C., are given on pages 13, 14, and 15.

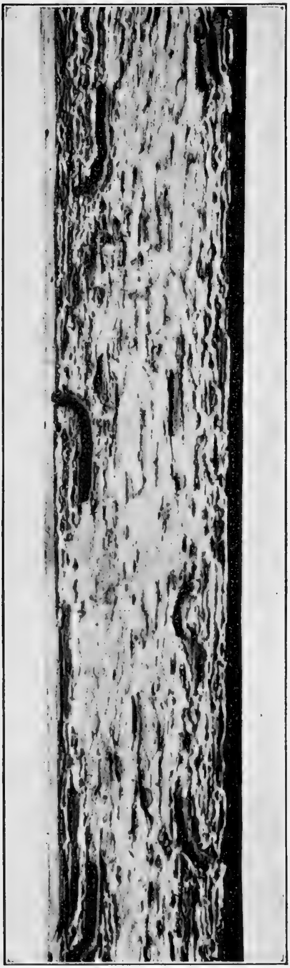

Fig. 9.—Pupal cells of *Lyctus planicollis* in powder-posted white-ash shovel handle. (Snyder.)

So far as known there is only one generation annually.

THE FOUR SPECIES RESPONSIBLE FOR MOST OF THE LOSSES.

While, as previously stated, there are many species of Lyctus beetles in the United States, the European Lyctus, the southern Lyctus, the velvety Lyctus, and the western Lyctus are the four species responsible for practically all the losses.

THE EUROPEAN LYCTUS.[1]

The European Lyctus beetle is rusty red-brown, slender, somewhat flattened, elongate, and from one-tenth to one-fifth inch in length. The wing covers have single rows of large, rounded, very shallow punctures.

This species is commonly met with in northern Europe under natural conditions as well as in commercial products, especially in England, France, and Germany. Therefore it is evident that it was introduced into this country from Europe. In addition to the wide distribution of this species in the temperate zones of the world, it is especially common and destructive in the States north of North Carolina, Tennessee, and Arkansas. There are a great many records of damage to seasoned hardwood products by this beetle from this area, including Maine, Massachusetts, New York, Pennsylvania, Virginia,

Fig. 10.—Pupa of a powder-post beetle, *Lyctus planicollis*. (Chittenden.)

[1] *Lyctus linearis* Goeze.

West Virginia, Ohio, Indiana, Illinois, Missouri, Iowa, Michigan, and Minnesota. The great number of specimens in the collection of the United States National Museum show but a single record from the South Atlantic and Gulf States, and this is evidently a temporary introduction. Undoubtedly the species is frequently carried into the southern region, but evidently it does not survive there. This beetle is common in commercial products of seasoned hickory, oak, walnut, and ash, and occasionally in poplar, wild cherry, and locust. It is not recorded from natural growth in the open in this country, but is said to infest such growth, as well as commercial products, in Europe.

Adults of the European species, which has been shown to have a relatively northern distribution in the United States, begin activity as early as the first part of March in its southern distribution and are still active during the first part of August in its northern distribution, general emergence of the adult beetles from infested wood occurring at Washington, D. C., from April until June. The eggs are deposited soon after the adult beetles emerge and are inserted into the pores of the wood by means of a long, slender, flexible ovipositor. The winter is passed in the larval stage in the wood. General pupation occurs from about the middle of April to the first of May in the District of Columbia.

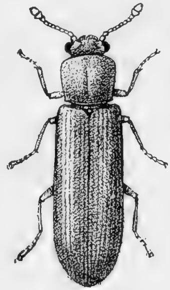

FIG. 11.—Adult powder-post beetle, *Lyctus planicollis*. (Chittenden.)

THE SOUTHERN LYCTUS.[1]

The southern Lyctus beetle is pitchy black, slender, somewhat flattened, elongate, and from one-tenth to one-fifth inch in length. The wing covers have smaller, finer, and deeper punctures in more or less distinct double rows. Individuals of this species vary extremely in size, and there is marked difference in size between the sexes, the males often being much smaller than the females. As the result of continued breeding in the same wood for several generations, in confinement the beetles were found to decrease in size.

This species is injurious to hardwood products in and from the South Atlantic and Gulf States to California, Arizona, and Nevada. This range probably represents the natural distribution of this southern species. It is frequently introduced into the Northern, Central, and Western States and transported to other countries, but this apparently never results in its permanent establishment except in warm storehouses. There are definite records of its occurrence at Cape

[1] *Lyctus planicollis* Lec.

Town, South Africa, in lumber received from the southern United States, and at Buenos Aires, Argentina, in the ash wood in refrigerators and shovel handles from the United States.

The southern Lyctus has been recorded as breeding under natural conditions in this country and is common in the Southern States in commercial products, such as seasoned ash, oak, hickory, persimmon, and sycamore. Rearing records show that it may breed continuously in the same wood during a period of at least six years, or until all the wood tissue has been converted into powder. The beetles emerge from infested wood of commercial products in heated buildings much earlier than where exposed to outdoor conditions. Owing to the character of the class of commercial products infested by Lyctus beetles, which are often stored indoors, there apparently are no great differences in the periods of activity of adults of species of northern and southern distribution.

Adults of this southern species are active from the middle of February till the last of September in the South Atlantic and Gulf States. General emergence of the adult beetles and mating occur from the middle of April to June, and very few beetles emerge at Washington, D. C., after the first part of July. Egg laying occurs a few days after emergence, and the eggs hatch after a period of not longer than 10 days. The winter is passed as larvæ in the wood, and full-grown larvæ are in the pupal cells at Washington by the first part of February. General pupation of the larvæ in the infested wood in rearing experiments at Falls Church, Va., occurred from about the middle of March to the first part of April.

THE VELVETY LYCTUS.[1]

The velvety Lyctus is rusty red-brown to black, slender, flattened, and elongate, and from one-twelfth to one-sixth inch in length. The punctures on the wing covers are very fine and obscure and not placed in rows; the fine, dense, yellowish hairs on the wing covers are prominent, which gives the beetle a velvety appearance.

Extensive observations have been made on the habits of this species, which has been recorded as injurious in Texas, Louisiana, Florida, Georgia, South Carolina, Virginia, West Virginia, District of Columbia, Long Island, New York, Ohio, and Missouri.

The natural distribution of the species is evidently in the South Atlantic and Gulf States and in part of the Mississippi and Ohio River Valleys, from which it has been temporarily introduced into other States.

This beetle infests the seasoned sapwood of commercial products made from persimmon, hickory, ash, oak, and bamboo; it also lives

[1] *Lyctus parallelopipedus* Melsh.

in the dead wood of natural growth of osage orange, sassafras, and fig.

Adults of the velvety Lyctus are active from the middle of March till the last of August at Washington, D. C. General emergence occurs from June to the last of July.

THE WESTERN LYCTUS.[1]

The western Lyctus is a rusty red-brown, slender beetle, somewhat flattened and elongate, and from about one-seventh to about one-fifth inch in length; the punctures on the wing covers are very fine and placed in more or less distinct double rows.

This species is recorded from California in commercial products, seasoned orange wood and hickory, tanbark oak, and cordwood of live oak.

Adults of this species are active from April till the middle of September.

CONDITIONS FAVORABLE FOR ATTACK.

Second-growth white wood or sapwood of the finest quality of hardwoods, especially hickory, ash, and oak, which has been stored or piled in one place for two or three years or longer is especially liable to damage by Lyctus beetles. This is particularly the case if the material has not been handled or moved and if the old stock is allowed to accumulate. Refuse and useless sapwood material and infested stock piled about the sheds or yards, sapwood piling sticks, etc., are sources of infestation. If the different species of hardwoods are not placed in separate piles, the species of woods not so liable to attack often become infested.

CONDITIONS UNFAVORABLE FOR ATTACK.

Material of species other than hickory, ash, and oak is less liable to attack. Sapwood seasoned for less than 8 to 10 months will not be attacked, and *heartwood is never attacked*[2] (fig. 12).

The conditions will be rendered very unfavorable for attack by powder-post beetles wherever hardwood stock in yards and storehouses is handled as follows: Material inspected and rehandled annually, preferably in November and February, and that showing evidence of powder-post attack sorted out and burned; all refuse and useless sapwood material burned; as far as practicable, all dry or seasoned hardwood stock separated into heartwood, pure sapwood, and part sapwood, and into hickory, ash, oak, etc., and classified according to the number of years it has been seasoned, *and the oldest*

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[1] *Lyctus cavicollis* Lec.

[2] Exhaustive strength tests conducted by the Forest Service show that the heaviest, and consequently the strongest, hickory averages below 10 rings per inch in rate of growth, and that, weight for weight, red hickory (heartwood) is as strong as white hickory (sapwood).

stock utilized and sold first; accumulations of refuse material in which the insects could breed prevented; the introduction into lum-

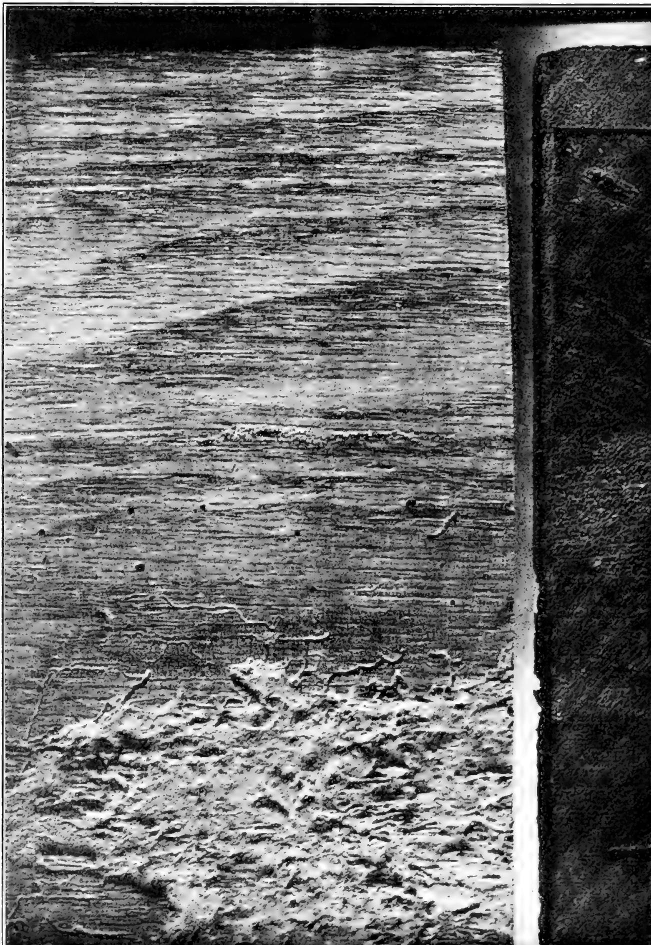

FIG. 12.—Powder-posted sapwood oak veneer laid on a core of chestnut (door stock); work of *Lyctus planicollis.* Note that the heartwood oak and the chestnut have not been attacked. (Original.)

ber yards and storehouses of material infested with powder post prevented; and, finally, heartwood instead of sapwood piling sticks used in the piles.

INSECT ENEMIES OF LYCTUS BEETLES.

There are many insect enemies of powder-post beetles. Among the beetles, species of the family Cleridae are often beneficial in checking the multiplication of Lyctus beetles, the larvæ preying on the Lyctus larvæ and the adults preying on the Lyctus adults. Other beetles which commonly prey upon the powder-post beetles belong to two other families.[1]

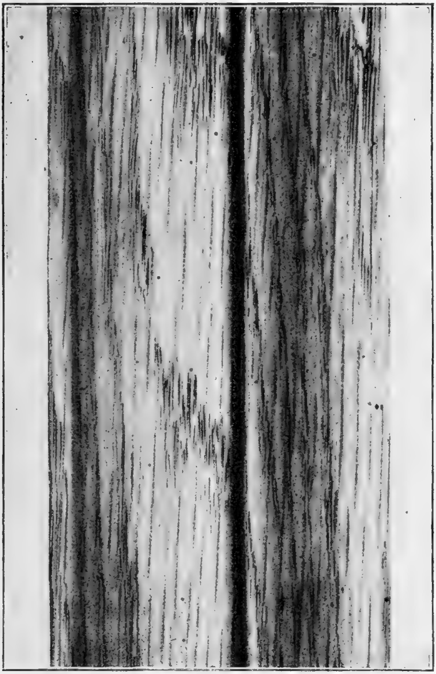

FIG. 13.—Exit holes of small, four-winged, wasplike parasites of Lyctus in powder-posted red oak interior finish. (Original.)

Many species of small, four-winged, wasplike parasites have the Lyctus beetles as their hosts. The emergence or exit holes of the adult parasites (fig. 13) are much smaller than those made by the beetles, but are often mistaken for those made by young Lyctus larvæ.

[1] Histeridae and Cucujidae.

In general, these insect enemies, although beneficial, can not be depended upon to keep the destructive beetles under control, and therefore usually can be disregarded when practical control measures are being instituted.

METHODS OF CONTROL.

The methods of combating this class of insects and of preventing losses from their ravages come under two primary heads: (1) The destruction of the insects, or remedies, and (2) prevention of attack.

REMEDIES.

Infested material, including infested sap edges of lumber, etc., and all refuse sapwood in which the insects might breed should be eliminated by sorting it out and disposing of it by burning or otherwise. All material showing the slightest evidence of powder-post damage should be discarded and destroyed, except possibly such articles as may be tested for required strength and found to be of sufficient value for retention after treatment.

Material slightly infested and damaged should be treated with kerosene oil, after which it should be kept in quarantine a sufficient length of time to determine whether a second treatment is required.

All partially damaged material, such as the sap edges of lumber and parts of other material too valuable to be destroyed, should, when practicable, have the damaged and infested parts cut away and burned.

The work should be done between October and the first of March in storehouses, and before the first of April in the open. If this is thoroughly done and, by annual inspection thereafter, infested material is disposed of as soon as found, there will soon be no trouble from this source, unless there is a continued introduction in lumber and material received from other yards and localities where methods of control are neglected. To avoid this, all material should be carefully inspected before shipment, or at least before it is placed in the yards or storehouses.

Where it is not practicable to remove the infested parts, or in case of the more valuable stock, the wood should be subjected to methods of treatment for the destruction of the insects between October and the first of March. Of the following remedies, that most suitable in each case should be selected, remembering that the treatment must not be detrimental to the wood for subsequent uses.

(1) Liberal applications of pure kerosene oil with a brush, or immersion of infested wood in vats of kerosene. The only objection to kerosene is the fire risk. However, kerosene soon evaporates, so that the treated material is not long near the danger point. Kero-

sene oil does not affect the application of shellac or varnish; the only effect on finishing is to make it more difficult to stain kerosene-treated sapwood to match the rest.

(2) Mixtures of 3 parts creosote and 1 part kerosene oil; 3 parts kerosene oil and 1 part creosote (to obtain a deeper penetration); and 1 part creosote and 3 parts naphtha have been used successfully. The wood should be dipped in vats of preservative, preferably heated by coils of steam pipe, or the preservative may be applied hot with a brush. *Of course, mixtures containing kerosene oil should not be heated over a direct fire.*

(3) Thorough steaming of the infested wood in a tight room or under pressure. Steaming under pressure weakens and discolors the wood and should not be applied to wood to be used for fine finish or where strength is essential.

(4) Subjecting seasoned wood to temperatures over 200° F. in dry kilns.

(5) Fumigation of infested wood in tightly closed drying rooms with the fumes of sulphur at the time of the emergence of the adult beetles. This has been recommended for killing the beetles and preventing egg laying.

The objection to treating infested material lies in the fact that if it is once infested it may be damaged beyond repair and not safe for future use. A break might result in a serious accident and reflect on the reputation of the manufacturer or distributor.

PREVENTION OF DAMAGE.

By the adoption of the following system of inspection, classification, and the proper disposal of the seasoned sapwood of hardwood stock, loss by powder-post beetles can be prevented:

(1) Inspect material in yards and storehouses annually, especially stock two or more years old, preferably in November and February. Then (a) sort out and burn material showing evidence of powder-post attack and (b) burn all useless sapwood material.

(2) Classify all dry or seasoned hardwood stock as (a) hickory, ash, oak, etc.; (b) heartwood, pure sapwood, and part sapwood; and (c) according to age, that is, the number of years it has been seasoned.

(3) *Utilize or sell oldest stock on hand first. Prevent the accumulation of old stock; in other words, keep the stock moving.*

(4) Prevent the accumulation of refuse material in which the insects can breed.

(5) Use only heartwood piling sticks in lumber piles.

(6) Inspect all new stock to prevent the introduction into lumber yards and storehouses of powder-posted material.

(7) If the beetles have not been eliminated from the yards and storehouses, stock that has been seasoned longer than eight months,

and which is to be held in storage, may be rendered immune by treating it with two coats of boiled linseed oil applied hot, or it may be immersed in vats of hot oil. The boiled oil will dry more rapidly than the raw linseed oil, especially if kerosene is added to the hot oil. The wood should be treated between October and the 1st of March.

Linseed oil has an advantage over other substances in that it can also be profitably applied to unseasoned timber, since it will prevent checking in seasoning. This oil stains the wood slightly yellow. In case of wagon stock, however, it can be used without prejudice to the trade and is an effective preventive.

Creosotes can be effectively used in case of stock to which the brown stain will not be detrimental. The wood should be dipped in vats of hot creosote, or the preservative should be applied hot with a brush.

In case of finished products or more valuable material, any substance which closes the pores of the wood may be effectively applied. For example, paraffin wax, varnish, etc., effectively close the pores of the wood and prevent the beetles from depositing the eggs, which are laid in these pores. Thus the sapwood portions of backs and interior surfaces of cabinet work, inside finish, and furniture, etc., should also be treated to prevent attack.

In conclusion it may be stated that while there are a number of effective chemical treatments to prevent attack, and to kill the insects after they get into the wood, the great objection to all of them is the great and recurring expense of treating material that never would be attacked if, by the proper methods of management, the premises were kept free from the pest.

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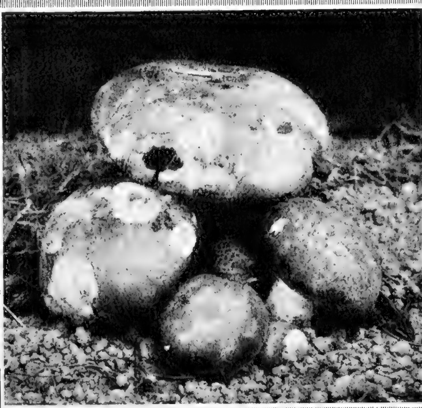
U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 789

MUSHROOM PESTS AND HOW TO CONTROL THEM



IN THE construction of a mushroom house, care should be taken to make the building as tight as possible, with outlets capable of being tightly closed. All windows and ventilators should be screened with fine wire gauze; this forms an excellent prevention against the entrance of both fungus gnats and the mites which they carry.

Mushroom spawn should be purchased only from reliable dealers.

The preparation of the compost should be careful and thorough, and the temperature of the house should be kept as low as possible, preferably below 55° F., thus reducing to a minimum the multiplication of any insects which may be present.

If the manure is carefully selected and properly composted and the temperature and moisture conditions are right, it should seldom be necessary to resort to such radical measures as fumigation, sterilization, or the destruction of the beds.

Washington, D. C. Issued February, 1917; revised July, 1925

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MUSHROOM PESTS AND HOW TO CONTROL THEM

By C. H. Popenoe, *Associate Entomologist, Truck-Crop Insect Investigations, Bureau of Entomology*

INTRODUCTION

CULTIVATED mushrooms are subject to attack by a variety of pests, especially during warm weather. Some of these may be brought into the house in the compost of which the beds are composed, attacking the mushrooms through preference, while others feed normally upon mushrooms, and are attracted from the wild forms outside through the greater abundance of their natural food plant in the cultivated beds. Injury by these pests frequently becomes serious. This bulletin treats of the measures for the protection of the crop from such injury.

The insect and other pests which usually attack cultivated mushrooms, and those of which complaints are most frequently made, may be divided roughly into four classes, namely, mushroom maggots, mites, springtails, and sowbugs. Of these the maggots are tne most generally injurious, the mites following in order of importance, owing to the difficulty with which their eradication is accomplished, and then come springtails and sowbugs in the order named.

MUSHROOM MAGGOTS

The injurious forms commonly known as "mushroom maggots" are small, whitish or yellowish-white maggots, usually having black heads. They are the larvæ, or young, of certain small, two-winged fungus gnats or flies, usually black or blackish in color, and belonging to several species.[1] They are minute, measuring only about one-tenth inch in length and about one-eighth inch in spread of wings. They are rapid and prolific breeders, especially during warm weather, frequently occurring in mushroom houses so abundantly as to darken the windows. They may be readily confused, however, with gnats of the same genus which breed in manure or in greenhouse soil, and determinations of the species should always be made by a specialist.

The life history of a mushroom maggot is about as follows:

The eggs, of which each female is capable of laying nearly 1,000, usually are deposited at the juncture of the stem and cap of the mushroom or in the manure or soil at its base. In a warm temperature they may hatch within three days, but in colder weather this time is considerably extended. Upon hatching, the larvæ bore at once into the stem or cap of the mushroom, soon riddling the cap and causing the "breaking down" of the mushroom. On account of the perishable nature of their host they must necessarily pass through their transformations quickly. The larvæ feed from seven to ten days, by which time

Fig. 1.—A mushroom fly, *Aphiochaeta albidihalteris:* Male. Much enlarged

the entire cap is destroyed; they then enter the ground, each spinning a slight silken cocoon just beneath the surface, and pupate. The pupa stage lasts from four to seven days, after which the insects emerge as adults and soon pair and lay eggs for the next generation. Owing to the immense number of eggs deposited and to the short life cycle, the rapidity of their increase is remarkable, so that the presence of only a few insects in the mushroom house at the beginning of the season may result in millions after the beginning of warm weather, thus effectually preventing the cultivation of mushrooms.

CONTROL

Where it is possible to keep the temperature of the mushroom house

[1] The species attracting the most attention as pests are *Sciara multiseta* Felt, *Sciara agraria* Felt, and *Aphiochaeta albidihalteris* Felt (see fig. 1). They belong to the two families of flies known as Mycetophilidae and Phoridae.

at 55° F. or to reduce it to that temperature upon indications of attack by maggots, damage by these pests is easily controlled. Otherwise it is evident that, in the control of the mushroom maggots, measures should be undertaken early in the season for their elimination from the mushroom house and precautions observed against their subsequent entrance. These precautions should begin with the construction of the house or cellar. The building should be so constructed as to permit of effective fumigation and should be fitted with tight screens of fine wire gauze, suitable to prevent the ingress of the fungus gnats. The gnats may also be brought into the house through the agency of the manure used in the beds, especially if the compost is carelessly prepared. In large commercial houses the care taken to secure uniformity in the fermentation of the compost renders improbable any danger from this source, since a uniform heat of 150° F. or more is frequently attained in the process, this being sufficient to destroy maggots and other pests which may be present. Fumigation with carbon disulfide just previous to spawning is also productive of good results in destroying maggots in the compost. The disulfide should be used at a strength of 2 to 4 pounds to 1,000 cubic feet of space and should be evaporated in shallow pans placed in the highest part of the house. *The liberated vapor of carbon disulfide is very inflammable and when mixed with air is explosive if brought into contact with fire or sparks, so that care should be used to avoid bringing any fire into the building during the process of fumigation.*

One of the best methods for the destruction of the adults or flies in their occurrence in mushroom houses is fumigation with tobacco or nicotine preparations, such as are used in greenhouses. These should be used in accordance with the directions indicated on the package for a medium or heavy fumigation.[2] Used in this manner and applied once a week during the bearing season of the mushroom bed, this method has been so successful in reducing the number of flies that very little damage, if any, resulted from the larvæ.

Hydrocyanic-acid gas is an effective fumigant against these pests where a good system of ventilation is provided. The most satisfactory dosage is at the rate of 3 ounces of sodium or calcium cyanide to each 1,000 cubic feet of space. The fumigation should be applied while the atmosphere of the house is relatively dry, for if undertaken immediately after the beds have been sprinkled down some burning of the crop may result. A good practice is to fumigate two or three times a week over a period of two weeks, releasing the gas in the evening and ventilating the houses before sprinkling down the following morning. As the gas is extremely poisonous, the operator should familiarize himself with the necessary precautions to be observed in its application, as outlined in Farmers' Bulletin 880 on greenhouse fumigation. Several large commercial mushroom growers have reported material benefits from the establishment of this practice.

Fumigation with best quality fresh pyrethrum insect powder or dusting the powder over the beds is also effective against the mushroom maggots if taken in time, but tobacco fumigation may be considered standard for this use.

THE MUSHROOM MITE

The mushroom mite[3] (fig. 2) is a minute, soft-bodied mite, smooth skinned, and white or whitish in color. It is closely allied to the common cheese mite[4] and resembles that species in appearance. It is, if anything, more prolific, becoming at times so abundant in mushroom beds as to cover the surface of the compost; when present in such numbers it is extremely destructive, feeding upon the mushrooms in all stages and penetrating the beds and destroying the mycelium.[5] Indeed, in one case observed, the mycelium was destroyed as fast as it was produced.

This species is undoubtedly the cause in many cases of the failure of the spawn to propagate, which is likely to be attributed to poor or weak spawn or to defective cultural conditions. The minute size of the mites causes their presence to be overlooked and the failure of the spawn to produce mycelium is not understood. Even under conditions favorable to the growth of the mycelium it is possible for the mites to increase to such an extent that the entire bed may be killed out.

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[2] The proportion of nicotine in the several preparations varies to such an extent that no standard dose has as yet been formulated.

[3] *Tyroglyphus lintneri* Osb.

[4] *Tyroglyphus siro* L.

[5] The term mycelium, as used herein, is applied to the new growth of spawn through the compost, as differentiated from the original insertions of spawn.

Besides the injury to the mycelium, mushroom mites cause damage to the fruiting bodies by eating into them, distorting or destroying the younger growth. In the more mature mushrooms the mites may be found clustered in groups consisting of individuals of many sizes, usually hidden in the folds between the gills, where they burrow into the tissue, causing the caps to break down.

No direct observations on the life history of this species have been made, but judging from that of related species it is about as follows: The eggs, which are large in proportion to the size of the mites, are laid in or about the mycelium or on the young developing caps. They hatch in a short time into the characteristic 6-legged young, which soon become mature. The time from the deposition of the egg to the maturity of the mite has not, so far as the writer knows, been worked out accurately, but it undoubtedly occupies only a few days. It is on this account that the mite is able to increase so rapidly, apparently as if by magic, and thus give rise to the theory of spontaneous generation sometimes advanced to explain this condition.

Under certain conditions the hypopus, or migratory, stage is produced. This stage, so far as known, is peculiar to the family Tyroglyphidae, to which this mite belongs, and is very remarkable. The mite develops a hard, chitinous covering, has no mouth parts, and is provided with short legs insufficient for walking. On the ventral surface of the body is an area provided with sucking disks, by means of which the hypopus attaches itself to an insect and is so transported to suitable breeding grounds in other localities. On arrival at a suitable breeding place the mite detaches itself from its insect host, molts, and soon becomes adult. During the hypopus stage the mite takes no food and causes no injury to the insect which carries it. This peculiar stage is the natural means for the distribution of the mite to new localities and is in many cases responsible for its appearance in localities far from previously infested beds.

In addition to the means mentioned above the mite may obtain access to mushroom houses in infested compost or in spawn from infested houses. The greater part of the infestation, however, probably takes place through the agency of the small flies which frequent mushroom houses and which carry the hypopus stage of the mite from one house to another.

REMEDIES

Little can be recommended for the control of the mushroom mite after it has once become established in a house. Owing to the absence of breathing pores it is practically unaffected by fumigants suitable for the control of other mushroom pests, and applications of sulfur, tobacco dust, and other insecticides to the beds seem only to prove slightly inconvenient to the mite. It is one of the most stubborn pests encountered in mushroom culture and may be brought into the house in almost any manure that is used for the bed. When in the hypopus stage it is capable of prolonged suspension of vitality and is likely to remain in the house for an almost unlimited time without death. The only measures, therefore, that may be considered are those of prevention.

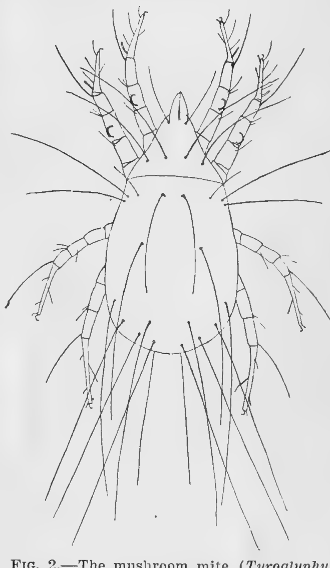


FIG. 2.—The mushroom mite (*Tyroglyphus lintneri*). Highly magnified. (Banks)

When an infested house is to be cleaned all compost should be gathered with the utmost care, removed to the outside, and thoroughly disinfected by drenching with boiling water, or it may be hauled to a distance and spread upon the ground as fertilizer or destroyed by burning. The ground occupied by the mushroom beds should be thoroughly scalded, and the woodwork of the mushroom house treated to a wash of creosote or crude carbolic acid, either of which is repellent to the mites. After complete disinfection has been accomplished the house should be screened, to guard against subsequent introduction of the pest by means of flies. Care should be used to purchase spawn coming from reliable sources. With these precautions it is unlikely that trouble will be experienced from the attacks of mushroom mites. Close watch should be kept, however, for any signs of their presence in the beds, and the compost destroyed upon their first abundant appearance, as it is impossible to obtain good results with mushrooms when they are once thoroughly infested by these mites. All applications of sufficient strength to destroy the mites are likewise injurious to the mushrooms, and it is futile to attempt to control them by any artificial means once the mushroom bed has become infested, as the mites are buried so deeply in the compost that no insecticide will reach them.

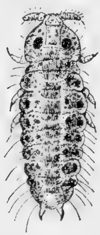


Fig. 3.—A common injurious springtail, *Achoreutes armatum.* Much enlarged

A predacious mite, which belongs to another family,[6] frequently occurs in beds infested by the mushroom mite, feeding upon the latter, and at times becoming so numerous as entirely to wipe out the pest. This predacious mite may be known by its reddish or brownish color, its longer legs, and its manner of running swiftly over the compost or the mushrooms. Cases have been observed where it has occurred in such abundance as greatly to outnumber its host. It does not attack the mushrooms after the destruction of the mushroom mite, but seeks other feeding grounds or dies of starvation.

SPRINGTAILS

At times the surface of a mushroom bed becomes alive with minute brown or black insects which, when disturbed, leap about like fleas in an extremely erratic manner. These are known as springtails,[7] since the springing is performed by the aid of two short bristles situated on the end segment of the abdomen. These insects (see fig. 3) are often attracted to the manure used as compost, where they feed on the decaying vegetable matter present, but on occasion they may become very injurious in mushroom houses. A correspondent in St. Louis, Mo., reported that in one of his mushroom houses a bed 150 feet in length had been completely destroyed by these pests, which attacked the mushrooms as fast as they appeared, honeycombing them and rendering them unfit for use. The method of attack of this insect is to feed upon the fruiting bodies of the mushrooms, destroying both the gills and the cap. Hundreds may be found clustered upon a single mushroom and eating large cavities in the gills. It appears to be a habit of these insects to congregate in large numbers on caps which have been slightly injured, in which case they rapidly destroy mushrooms which would be readily salable if the injury were not continued. When they occur in large numbers they are likely to attack even perfect mushrooms, in aggravated cases destroying whole beds.

Insects of this group pass through no larval transformation, the form of the newly hatched young being similar to that of the adult. They are thus likely to be injurious in the same manner throughout their life history.

REMEDIES

The remedial measures applicable to the control of springtails are to a large extent preventive, as these insects are somewhat difficult to destroy when once established in a mushroom bed. Springtails are quite resistant to tobacco powders, but applications of "buhach" or pyrethrum insect powder to the beds are productive of some good. As they usually congregate near the surface of the beds, fumigation with hydrocyanic-acid gas, as for the mushroom fly (p. 2), will prove effective in reducing their numbers and will not prove injurious to the mycelium. The fumigation should be applied after picking, as an excessive strength of the gas is likely to "burn" the caps severely, causing them to turn brown.

By way of prevention, it is better, where possible, to grow the mushrooms at a temperature of about 55°

[6] Gamasidae.

[7] *Achoreutes armatum* Nicolet et al.

F. than higher, since at low temperatures the springtails breed more slowly. Dusting the tops of the beds with powdered lime is also said to discourage attack by springtails.

SOWBUGS

Considerable injury is often accomplished to mushroom beds through the attacks of oval, grayish or slate-colored creatures bearing seven pairs of legs. These creatures are not true insects, although known variously by the terms "wood lice," "sowbugs," and "pillbugs." Two species, the greenhouse pillbug[8] and the dooryard sowbug[9] are illustrated in Figures 4, 5, and 6.

Sowbugs frequent damp, dark places, such as those beneath boards, in cellars, and in the cracks of sidewalks. When disturbed many species roll up to form a ball, lying quite still until the danger is past. (See fig. 5.) During the night they issue from their hiding places to feed upon decaying vegetable matter, molds, and other material present in damp soils, although at times the roots of plants and even the green leaves are not eschewed.

The young are carried about in a pouch, formed by several modified anal plates on the abdomen of the female, until able to shift for themselves. When released by the female the young are similar in appearance to the adults, although much smaller, and are likewise capable of damage. There is probably only one generation annually, the young making their appearance in the spring and requiring one summer to reach maturity.

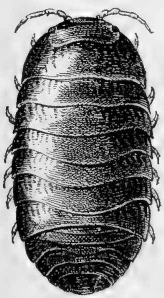


FIG. 4.—The greenhouse pillbug (*Armadillidium vulgare*) extended. Much enlarged

The destruction occasioned by sowbugs is due to their attacks on the caps or fruiting bodies of mushrooms. These they attack while quite small, destroying them or injuring their appearance. They do not, as a rule, attack the mycelium, but eat holes in the young "buttons," which, on the completion of the growth, become much larger and disfigure the product.

Sowbugs are frequently carried into the mushroom house in compost which has been allowed to stand outside. The heat of the manure is relished by them, and they collect in numbers, remaining throughout the growth of the spawn and becoming injurious with the first growth of the mushrooms.

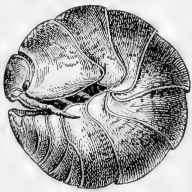


FIG. 5.—The greenhouse pillbug (*Armadillidium vulgare*) contracted. Much enlarged

The writer has seen sowbugs congregated in manure piles to such an extent that numbers aggregating a pint or more in quantity might have been collected from a shovelful of material.

REMEDIES

Where the mushroom house is small in extent it is possible materially to reduce the number of sowbugs by means of hand picking. The house may be visited at night, when by the aid of a lantern numbers of sowbugs may be seen crawling about on the earthen casing of the beds and upon the boards and supports of the benches. These may be destroyed with a small wooden paddle.

It is also possible to obtain good results by pouring hot water along the cracks in the boards and in other places where the "bugs" may be concealed by day. This is effective in small establishments, but is somewhat difficult of application in large houses. In such a case fumigation with hydrocyanic-acid gas is an effective remedy.

Another method is to cut small pieces of raw potato, plastering the wet surface with Paris green, and lay them on the beds in the localities affected by the sowbugs. This method is frequently successful in entirely ridding houses of this pest.

A modification of this treatment successfully used by the writer in the

[8] *Armadillidium vulgare* Latreille. [9] *Porcellio laevis* Koch.

destruction of sowbugs in greenhouse benches is the application of the ordinary poisoned-bran mash commonly recommended for the destruction of cutworms and grasshoppers. This bait is prepared as follows:

Bran	pounds	25
Paris green or white arsenic	do	1
Oranges or lemons		6
Cheap sirup or molasses	quarts	2
Water	gallons	4

The bran should be placed in a washtub or similar container and the poison added while dry. These should be thoroughly mixed and then the water, to which has been added the sirup and the finely chopped fruit,

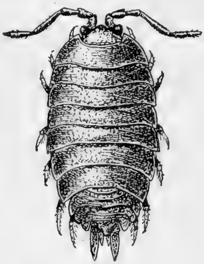


FIG. 6.—Dooryard sowbug (*Porcellio laevis*). Much enlarged

should be stirred into the mixture until a wet mash is formed. After the mash is allowed to stand an hour or two, it may be scattered thinly on the infested beds.

SLUGS

The appearance of conspicuous, ragged holes eaten into the caps of mushrooms (see illustration on title page) during the night may often be traced to the presence of the large imported garden slug.[10] These unpleasant creatures are extremely fond of mushrooms, issuing from their hiding places toward evening and, leaving a trail of slime behind them, proceeding in search of their favorite food.

The damage to mushrooms is not confined to the cultivated species, but may frequently be observed in those growing in woods and fields. It is characterized by the rough, gouged-out appearance of the holes, which seem as though excavated by a mouse or rat. The creature itself resembles a shell-less snail from 2 to 7 inches in length and is grayish brown to pitchy black in color, usually with numerous elongate black spots. The eyes are borne on two pedicels or stalks, which are retracted within the body when the mollusk is disturbed.

The imported garden slug deposits its large, round, transparent, yellowish eggs in gelatinous clusters beneath boards or refuse over moist earth. There is one brood each year, the young hatching in the spring and becoming half grown by fall. As with other mollusks, life extends over a period of several years. The individuals usually frequent moist spots in gardens or lawns and feed on the herbage, but frequently they invade mushroom houses, where their injury becomes almost immediately noticeable.

REMEDIES

The usual remedy for slugs, trapping by means of poisoned or other baits, is inapplicable when these creatures occur in mushroom houses, since they prefer fresh mushrooms to any other food which might be used. It is therefore necessary to use hand methods of collection, such as are mentioned under the head of "Sowbugs." Such measures should be undertaken as soon as the injury is noticed, for if individuals are allowed to breed in the house their elimination will be much more difficult. Advantage may be taken of the habit of these slugs of returning to the same place of concealment each day, and they may be sought out with a lantern and destroyed or captured during the night while engaged in feeding. They are repelled by dust, powdered lime, or ashes and will not cross a line composed of one of these substances. Small beds may thus be protected from their ravages—for a time at least. Pulverized salt is another valuable deterrent.

CRICKETS

Among other injurious forms which at times attack mushroom beds, certain crickets are reported as eating into the caps of the mushrooms.[11]

The remedies for crickets in their injurious occurrence are the same as those recommended for sowbugs. Potatoes and carrots may be minced before the Paris green is applied, in order that a somewhat thicker coat may be secured.

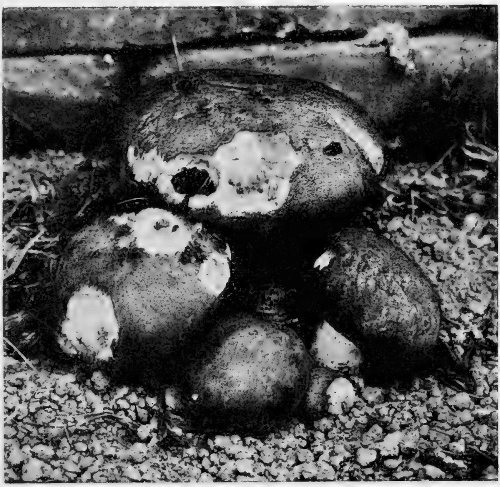
[10] *Limax maximus* L.

[11] On the Pacific coast a "camel-cricket" known scientifically as *Pristoceuthophilus pacificus* Thom. has been reported as causing extensive injury to cultivated mushroom beds.

MUSHROOM PESTS AND HOW TO CONTROL THEM

C. H. POPENOE

Entomological Assistant, Truck Crop and Stored Product Insect Investigations



FARMERS' BULLETIN 789

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C. February, 1917

IN THE construction of a mushroom house, care should be taken to make the building as tight as possible, with outlets capable of being tightly closed. All windows and ventilators should be screened with fine wire gauze; this forms an excellent prevention against the entrance of both fungus gnats and the mites which they carry.

Mushroom spawn should be purchased only from reliable dealers.

The preparation of the compost should be careful and thorough, and the temperature of the house should be kept as low as possible, preferably below 55° F., thus reducing to a minimum the multiplication of any insects which may be present.

If the manure is carefully selected and properly composted and the temperature and moisture conditions are right, it should seldom be necessary to resort to such radical measures as fumigation, sterilization, or the destruction of the beds.

MUSHROOM PESTS AND HOW TO CONTROL THEM.

CONTENTS.

INTRODUCTION.

CULTIVATED mushrooms are subject to attack by a variety of pests, especially during warm weather. Some of these may be brought into the house in the compost of which the beds are composed, attacking the mushrooms through preference, while others feed normally upon mushrooms, and are attracted from the wild forms outside through the greater abundance of their natural food plant in the cultivated beds. Injury by these pests frequently becomes serious. This bulletin treats of the measures for the protection of the crop from such injury.

The insect and other pests which usually attack cultivated mushrooms, and those of which complaints are most frequently made, may be divided roughly into four classes, namely, mushroom maggots, mites, springtails, and sowbugs. Of these the maggots are the most generally injurious, the mites following in order of importance, owing to the difficulty with which their eradication is accomplished, and then come springtails and sowbugs in the order named.

MUSHROOM MAGGOTS.

The injurious forms commonly known as "mushroom maggots" are small, whitish or yellowish-white maggots, usually having black heads. They are the larvæ, or young, of certain small, two-winged fungus gnats or flies, usually black or blackish in color, and belonging to several species.[1] They are minute, measuring only about one-tenth inch in length and about one-eighth inch in spread of wings. They are rapid and prolific breeders, especially during warm weather,

[1] The species attracting the most attention as pests are *Sciara multiseta* Felt, *Sciara agraria* Felt, and *Aphiochaeta albidihalteris* Felt (see fig. 1). They belong to the two families of flies known as Mycetophilidae and Phoridae.

frequently occurring in mushroom houses so abundantly as to darken the windows. They may be readily confused, however, with gnats of the same genus which breed in manure or in greenhouse soil, and determinations of the species should always be made by a specialist.

The life history of a mushroom maggot is about as follows:

The eggs, of which each female is capable of laying nearly 1,000, generally are deposited at the juncture of the stem and cap of the mushroom or in the manure or soil at its base. In a warm temperature they may hatch within 3 days, but in colder weather this time is considerably extended. Upon hatching, the larvæ bore at once into the stem or cap of the mushroom, soon riddling the cap and causing the "breaking down" of the mushroom. On account of the perishable nature of their host they must necessarily pass through their transformations quickly. The larvæ feed from 7 to 10 days, by which time the entire cap is destroyed; they then enter the ground, each spinning a slight silken cocoon just beneath the surface, and pupate. The pupa stage lasts from 4 to 7 days, after which the insects emerge as adults and soon pair and lay eggs for the next generation. Owing to the immense number of eggs deposited and to the short life cycle, the rapidity of their increase is remarkable, so that the presence of only a few insects in the mushroom house at the beginning of the season may result in millions after the beginning of warm weather, thus effectually preventing the cultivation of mushrooms.

FIG. 1.—A mushroom fly, *Aphiochaeta albidihalteris*: Male. Much enlarged. (Author's illustration.)

CONTROL.

Where it is possible to keep the temperature of the mushroom house at 55° F. or to reduce it to that temperature upon indications of attack by maggots, damage by these pests is easily controlled. Otherwise it is evident that, in the control of the mushroom maggots, measures should be undertaken early in the season for their elimination from the mushroom house and precautions observed against their subsequent entrance. These precautions should begin with the construction of the house or cellar. The building should be so constructed as to permit of effective fumigation and should be fitted with tight screens of fine wire gauze, suitable to prevent the ingress of the fungus gnats. The gnats may also be brought into the house through the agency of the manure used in the beds, especially if the compost is carelessly prepared. In large commercial houses the care taken to secure uniformity in the fermentation of the compost renders improbable any danger from this source, since a uniform heat of 150° F. or more is frequently attained in the process, this being sufficient to destroy maggots and other pests which may be present. In case of serious infestation of the compost before planting, however, it may be well to disinfect or sterilize this substance by means of steam heat. This may be accomplished for small houses by placing the manure or soil in vats or boxes through which steam pipes are conducted. (See fig. 2.) In large mushroom houses, which are heated by steam, a number of pipes may be laid beneath the surface of the beds, in a manner similar to that used in greenhouses for sterilizing the soil of the benches. The manure should be heated to a temperature of 150° F., which will destroy all animal life occurring therein without injury to its capacity for producing mushrooms. Fumigation with carbon disulphid just previous to spawning is also productive of good results in destroying maggots in the compost. The disulphid should be used at a strength of 2 to 4 pounds to 1,000 cubic feet of space and should be evaporated in shallow pans placed in the highest part of the house. *Carbon disulphid is very inflammable and the liberated gas is explosive when brought into contact with fire or sparks, so that care should be used to avoid bringing any fire into the building during the process of fumigation.*

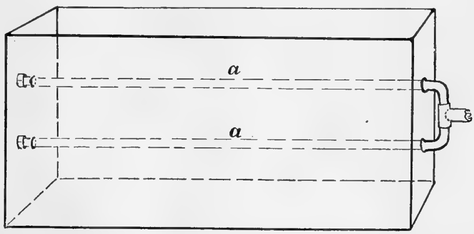


FIG. 2.—Steaming box, or sterilizer, for the treatment of compost. (Author's illustration.)

One of the best methods for the destruction of the adults or flies in their occurrence in mushroom houses is fumigation with tobacco or nicotine preparations, such as are used in greenhouses. These should be used in accordance with the directions indicated on the package for a medium or heavy fumigation.[1] Used in this manner and applied once a week during the bearing season of the mushroom bed, this method has been so successful in reducing the number of flies that very little damage, if any, resulted from the larvæ.

Fumigation with best quality fresh pyrethrum insect powder or dusting the powder over the beds is also effective against the mush-

[1] The proportion of nicotine in the several preparations varies to such an extent that no standard dose has as yet been formulated.

room maggots if taken in time, but tobacco fumigation may be considered standard for this use.

THE MUSHROOM MITE.

The mushroom mite[1] (fig. 3) is a minute, soft-bodied mite, smooth skinned, and white or whitish in color. It is closely allied to the common cheese mite[2] and resembles that species in appearance. It is, if anything, more prolific, becoming at times so abundant in mushroom beds as to cover the surface of the compost; when present in such numbers it is extremely destructive, feeding upon the mushrooms in all stages and penetrating the beds and destroying the mycelium.[3] Indeed, in one case observed, the mycelium was destroyed as fast as it was produced.

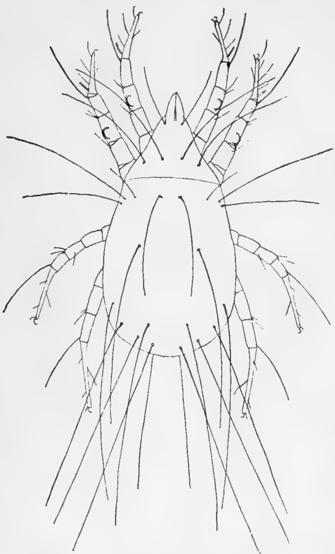


FIG. 3.—The mushroom mite (*Tyroglyphus lintneri*). Highly magnified. (Banks.)

This species is undoubtedly the cause in many cases of the failure of the spawn to propagate, which is likely to be attributed to poor or weak spawn or to defective cultural conditions. The minute size of the mites causes their presence to be overlooked and the failure of the spawn to produce mycelium is not understood. Even under conditions favorable to the growth of the mycelium it is possible for the mites to increase to such an extent that the entire bed may be killed out.

Besides the injury to the mycelium, mushroom mites cause damage to the fruiting bodies by eating into them, distorting or destroying the young growth. In the more mature mushrooms the mites may be found clustered in groups consisting of individuals of many sizes, usually hidden in the folds between the gills, where they burrow into the tissue, causing the caps to break down.

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[1] *Tyroglyphus lintneri* Osb.

[2] *Tyroglyphus siro* L.

[3] The term mycelium, as used herein, is applied to the new growth of spawn through the compost, as differentiated from the original insertions of spawn.

No direct observations on the life history of this species have been made, but judging from that of related species it is about as follows: The eggs, which are large in proportion to the size of the mites, are laid in or about the mycelium or on the young developing caps. They hatch in a short time into the characteristic 6-legged young, which soon become mature. The time from the deposition of the egg to the maturity of the mite has not, so far as the writer knows, been worked out accurately, but it undoubtedly occupies only a few days. It is on this account that the mite is able to increase so rapidly, apparently as if by magic, and thus give rise to the theory of spontaneous generation sometimes advanced to explain this condition.

Under certain conditions the hypopus or migratory stage is produced. This stage, so far as known, is peculiar to the family Tyroglyphidae, to which this mite belongs, and is very remarkable. The mite develops a hard, chitinous covering, has no mouth parts, and is provided with short legs insufficient for walking. On the ventral surface of the body is an area provided with sucking disks, by means of which the hypopus attaches itself to an insect and is so transported to suitable breeding grounds in other localities. On arrival at a suitable breeding place the mite detaches itself from its insect host, molts, and soon becomes adult. During the hypopus stage the mite takes no food and causes no injury to the insect which carries it. This peculiar stage is the natural means for the distribution of the mite to new localities, and is in many cases responsible for its appearance in localities far from previously infested beds.

In addition to the means mentioned above, the mite may obtain access to mushroom houses in infested compost or in spawn from infested houses. The greater part of the infestation, however, probably takes place through the agency of the small flies which frequent mushroom houses and which carry the hypopus stage of the mite from one house to another.

REMEDIES.

Little can be recommended for the control of the mushroom mite after it has once become established in a house. Owing to the absence of breathing pores it is practically unaffected by fumigants suitable for the control of other mushroom pests, while applications of sulphur, tobacco dust, and other insecticides to the beds seem only to prove slightly inconvenient to the mite. It is one of the most stubborn pests encountered in mushroom culture, and may be brought into the house in almost any manure that is used for the bed. When in the hypopus stage it is capable of prolonged suspension of vitality and is likely to remain in the house for an almost unlimited time without death. The only measures, therefore, that may be considered are those of prevention.

When a house becomes infested all compost should be gathered with the utmost care, removed to the outside, and thoroughly disinfected by drenching with boiling water, or it may be hauled to a distance and spread upon the ground as fertilizer or destroyed by burning. The ground occupied by the mushroom beds should be thoroughly scalded, and the woodwork of the mushroom house treated to a wash of creosote or crude carbolic acid, either of which is repellent to the mites. After complete disinfection has been accomplished the house should be screened, to guard against subsequent introduction of the pest by means of flies. All manure forming the beds should be steamed, according to the directions under the head of "Mushroom maggots." Care should be used to purchase spawn coming from reliable sources. With these precautions it is unlikely that trouble will be experienced from the attacks of mushroom mites. Close watch should be kept, however, for any signs of their presence in the beds, and the compost destroyed upon their first abundant appearance, as it is impossible to secure good results with mushrooms when they are once thoroughly infested by these mites. All applications of sufficient strength to destroy the mites are likewise injurious to the mushrooms, and it is futile to attempt to control them by any artificial means once the mushroom bed has become infested, as the mites are buried so deeply in the compost that no insecticide will reach them.

A predacious mite, which belongs to another family,[1] frequently occurs in beds infested by the mushroom mite, feeding upon the latter, and at times becoming so numerous as entirely to wipe out the pest. This predacious mite may be known by its longer legs and its manner of running swiftly over the compost or the mushrooms. Cases have been observed where it has occurred in such abundance as greatly to outnumber its host. It does not attack the mushrooms after the destruction of the mushroom mite, but seeks other feeding grounds or dies of starvation.

SPRINGTAILS.

At times the surface of a mushroom bed becomes alive with minute brown or black insects which, when disturbed, leap about like fleas in an extremely erratic manner. These are known as springtails,[2] since the springing is performed by the aid of two short bristles situated on the end segment of the abdomen. These insects (see fig. 4) are often attracted to the manure used as compost, where they feed on the decaying vegetable matter present, but on occasion they may become very injurious in mushroom houses. A correspondent in St. Louis, Mo., reported that in one of his mushroom houses a bed 150

[1] Gamasidae.

[2] *Achorutes armatum* Nicolet et al.

feet in length had been completely destroyed by these pests, which attacked the mushrooms as fast as they appeared, honeycombing them and rendering them unfit for use. The method of attack of this insect is to feed upon the fruiting bodies of the mushrooms, destroying both the gills and the cap. Hundreds may be found clustered upon a single mushroom and eating large cavities in the gills. It appears to be a habit of these insects to congregate in large numbers on caps which have been slightly injured, in which case they rapidly destroy mushrooms which would be readily salable if the injury were not continued. When they occur in large numbers they are likely to attack even the perfect mushrooms, in aggravated cases destroying whole beds.

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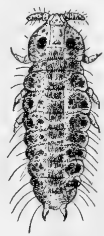

Fig. 4.—A common injurious springtail, *Achorutes armatum*. Much enlarged (Author's illustration.)

REMEDIES.

The remedial measures applicable to the control of springtails are to a large extent preventive, as these insects are somewhat difficult to destroy when once established in a mushroom bed. Springtails are quite resistant to tobacco powders, but applications of "buhach" or pyrethrum insect powder to the beds are productive of some good. As they usually congregate near the surface of the beds, fumigation with hydrocyanic-acid gas according to the directions given in Farmers' Bulletin 699 will prove effective in reducing their numbers. The cyanid should be used at a strength of from 3 to 6 ounces to each 1,000 cubic feet of air space, which will not prove injurious to the mycelium. The fumigation should be applied after picking, as the gas "burns" the caps severely, causing them to turn brown.

By way of prevention, steaming all manure, as previously suggested for other species, will destroy springtails. Where possible it is better to grow the mushrooms at a temperature of about 55° F. than higher, since at low temperatures the springtails breed more slowly. Dusting the tops of the beds with powdered lime is also said to discourage attack by springtails.

SOWBUGS.

Considerable injury is often accomplished to mushroom beds through the attacks of oval, grayish or slate-colored creatures bearing seven pairs of legs. These creatures are not true insects, although known variously by the terms "woodlice," sowbugs, and "pillbugs." Two species, the greenhouse pillbug[1] and the dooryard sowbug,[2] are illustrated in figures 5, 6, and 7.

Sowbugs frequent damp, dark places, such as those beneath boards, in cellars, and in the cracks of sidewalks. When disturbed, many species roll up to form a ball, lying quite still until the danger is past. (See fig. 6.) During the night they issue from their hiding places to feed upon decaying vegetable matter, molds, and other material present in damp soils, although at times the roots of plants and even the green leaves are not eschewed.

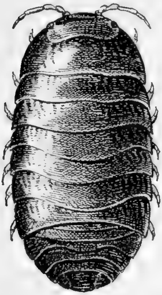

FIG. 5.—The greenhouse pillbug (*Armadillidium vulgare*) extended. Much enlarged. (Author's illustration.)

The young are carried about in a pouch, formed by several modified anal plates on the abdomen of the female, until able to shift for themselves. When released by the female the young are similar in appearance to the adults, although much smaller, and are likewise capable of damage. There is probably only one generation annually, the young making their appearance in the spring and requiring one summer to reach maturity.

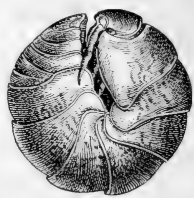

FIG. 6.—The greenhouse pillbug (*Armadillidium vulgare*) contracted. Much enlarged. (Author's illustration.)

The destruction occasioned by sowbugs is due to their attacks on the caps or fruiting bodies of mushrooms. These they attack while quite small, destroying them or injuring their appearance. They do not, as a rule, attack the mycelium, but eat holes in the young "buttons," which, on the completion of the growth, become much larger and disfigure the product.

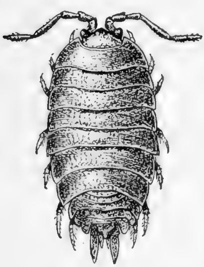

FIG. 7.—Dooryard sowbug (*Porcellio laevis*). Much enlarged. (Author's illustration.)

Sowbugs are frequently carried into the mushroom house in compost which has been allowed to stand outside. The heat of the manure is relished by them, and they collect in numbers, remaining throughout the growth of the spawn and becoming injurious with the first growth of the mushrooms. The writer has seen sowbugs collected in manure piles to such an extent that

[1] *Armadillidium vulgare* Latreille.
[2] *Porcellio laevis* Koch.

numbers aggregating a pint or more in quantity might have been collected from a shovelful of material.

REMEDIES.

Where the mushroom house is small in extent it is possible materially to reduce the numbers of sowbugs by means of hand picking. The house may be visited at night, when by the aid of a lantern numbers of sowbugs may be seen crawling about on the earthen casing of the beds and upon the boards and supports of the benches. These may be destroyed with a small wooden paddle.

It is also possible to secure good results by pouring hot water along the cracks in the boards and in other places where the "bugs" may be concealed by day. This is effective in small establishments, but is somewhat difficult of application in large houses. In such a case fumigation with hydrocyanic-acid gas is an effective remedy.

Another method is to cut small pieces of raw potato, plastering the wet surface with Paris green, and laying them about on the beds in the localities affected by the sowbugs. This method is frequently successful in entirely ridding houses of this pest.

A modification of this treatment successfully used by the writer in the destruction of sowbugs in greenhouse benches is the application of the ordinary poisoned-bran mash commonly recommended for the destruction of cutworms and grasshoppers. This bait is prepared as follows:

Bran	pounds	25
Paris green or white arsenic	do	1
Oranges or lemons	do	6
Cheap sirup or molasses	quarts	2
Water	gallons	4

The bran should be placed in a washtub or similar container and the poison added while dry. These should be thoroughly mixed and then the water, to which has been added the sirup and the finely chopped fruit, should be stirred into the mixture until a wet mash is formed. After the mash is allowed to stand an hour or two, it may be scattered thinly on the infested beds.

SLUGS.

The appearance of conspicuous, ragged holes eaten into the caps of mushrooms (see illustration on title page) during the night may often be traced to the presence of the large imported garden slug.[1] These unpleasant creatures are extremly fond of mushrooms, issuing from their hiding places toward evening, and, leaving a trail of slime behind them, proceeding in search of their favorite food.

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[1] *Limax maximus* L.

The damage to mushrooms is not confined to the cultivated species, but may frequently be observed to those growing in woods and fields. It is characterized by the rough, gouged-out appearance of the holes, which seem as though excavated by a mouse or rat. The creature itself resembles a shell-less snail from 2 to 7 inches in length and is grayish brown to pitchy black in color, usually with numerous elongate black spots. The eyes are borne on two pedicels or stalks which are retracted within the body when the mollusk is disturbed.

The imported garden slug deposits its large, round, transparent, yellowish eggs in gelatinous clusters beneath boards or refuse over moist earth. There is one brood each year, the young hatching in the spring and becoming half grown by fall. As with other mollusks, life extends over a period of several years. The individuals usually frequent moist spots in gardens or lawns and feed on the herbage, but frequently they invade mushroom houses, where their injury becomes almost immediately noticeable.

REMEDIES.

The usual remedies for slugs, trapping by means of poisoned or other baits, are inapplicable when these creatures occur in mushroom houses, since they prefer fresh mushrooms to any other food which might be used. It is therefore necessary to use hand methods of collection, such as are mentioned under the head of "Sowbugs." Such measures should be undertaken as soon as the injury is noticed, for if individuals are allowed to breed in the house their elimination will be much more difficult. Advantage may be taken of the habit of these slugs of returning to the same place of concealment each day, and they may be sought out with a lantern and destroyed or captured during the night while engaged in feeding. They are repelled by dust, powdered lime, or ashes and will not cross a line composed of one of these substances. Small beds may thus be protected from their ravages—for a time at least. Pulverized salt is another valuable deterrent.

CRICKETS.

Among other injurious forms which at times attack mushroom beds, certain crickets are reported as eating into the caps of the mushrooms.[1]

The remedies for crickets in their injurious occurrence are the same as those recommended for sowbugs. Potatoes and carrots may be minced before the Paris green is applied, in order that a somewhat thicker coat may be secured.

[1] On the Pacific coast a species known scientifically as *Ceuthophilus pacificus* Thom. has been reported as causing extensive injury to cultivated mushroom beds.

GENERAL SUMMARY.

In the construction of a mushroom house, care should be taken to make the building as tight as possible, with outlets capable of being tightly closed. All windows and ventilators should be screened with fine wire gauze; this forms an excellent prevention against the entrance of both fungus gnats and the mites which they carry, as previously mentioned. The importance of purchasing spawn from reliable dealers may be emphasized here. The preparation of the compost should be careful and thorough, and the temperature of the house should be kept as low as possible, preferably below 55° F., as at a low temperature all insects are more or less dormant, and their otherwise rapid multiplication is thereby reduced to a minimum, with corresponding reduction in infestation. Using carefully selected manure, properly composted, and with proper temperature and moisture conditions, there should be little necessity for the radical measures of fumigation, sterilization, or destruction of the beds.

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1917

THE SHEEP TICK

AND ITS ERADICATION BY DIPPING

MARION IMES
Zoological Division

FARMERS' BULLETIN 798
UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Animal Industry
A. D. MELVIN, Chief

Washington, D. C. May, 1917

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THE SHEEP TICK, while not a true tick, is a blood-sucking parasite which infests sheep on both farms and ranges. It is widely prevalent and spreads rapidly, especially among the close-herded range flocks, where it may cause much damage and loss. The nature and habits of the tick are described, also methods of identifying it.

The only practicable way of destroying the pest is by dipping the sheep. Two dippings are necessary, about 24 days apart, as the first dipping may not destroy all the pupæ (eggs), and these may subsequently hatch a new brood.

Several kinds of dips are used successfully. Of the home-made dips the one found to be most efficacious is the lime-sulphur-arsenic dip. Full directions for making this dip are given in this bulletin. Methods of dipping large and small flocks are discussed, including plans of a wooden and a cement vat, showing details of construction.

THE SHEEP TICK AND ITS ERADICATION BY DIPPING.

CONTENTS.

DISTRIBUTION AND ECONOMIC IMPORTANCE.

The sheep tick (*Melophagus ovinus*) is not a true tick but a wingless parasitic fly which passes the various stages of its life on the sheep. In many of the English-speaking countries it is known as the "ked" and is sometimes called the "louse fly" from its habit of living in the wool like a louse, but among the sheep growers of this country it is known as the sheep tick. It is widely distributed in many of the sheep-growing countries of the world, including the United States where it is known to occur in practically all of the States where sheep are kept. It is most prevalent, however, in the western range States where sheep are herded in large flocks. The northern two-thirds of the range country, or that part known as the Northwest, is the most heavily infested.

For a number of years it had been the custom in the majority of the principal sheep-growing States to dip the flocks regularly for scab. Such dipping evidently checked the spread of sheep ticks also, but as scab has been eradicated in many of the States compulsory general dipping for scab was discontinued in such areas, and especially in the Northwest. In the meantime the ticks spread rapidly and became prevalent in many of the flocks to such an extent that in some of the States compulsory general dipping was resumed in order to eradicate them. The sheep owners in some of the Southwestern States have continued to dip their flocks more or less regularly each season and consequently the ticks are not so plentiful in those areas. However, they are gaining a foothold in many of the flocks in this section, and conditions indicate that they may become a source of considerable loss if dipping is discontinued before they are eradicated.

Many of the farm flocks of the United States harbor sheep ticks and in some cases they are present in sufficient numbers to cause considerable damage to such flocks. This is especially true where open-fleece sheep are kept.

The sheep tick obtains its food by puncturing the skin of the sheep with its lance-like proboscis or sucking tube and feeding on the blood and lymph. The irritation thus caused is very great, especially in the case of lambs that are infested heavily, and while the quantity of blood drawn by one tick in 24 hours is small, the total amount taken by a large number of ticks is considerable and the drain constant. The irritation caused by the ticks makes the sheep restless so that they do not feed well, and in consequence, they do not grow and fatten as rapidly as when free from ticks. Thus a loss is caused by shrinkage in weight and a general unthrifty condition of infested flocks, with a consequent lowering of the vitality and a reduction in the resisting power of the animals. These conditions not only help to reduce the market value of the sheep but also tend to reduce wool growth, although being a bloodsucker, the tick does not feed on the yolk of the wool or directly injure the fibers to any great extent.

During the course of the investigations conducted by the Bureau of Animal Industry bearing on the problems of eradication, estimates of the average annual losses caused by sheep ticks were submitted by a large number of sheep owners in Utah. According to these estimates, the average annual losses are 25 cents per head for lambs and 20 cents per head for ewes in infested flocks. These figures are undoubtedly very conservative, as in estimating losses caused by parasites the indirect losses are seldom taken into consideration. Any factor operating to lower the vitality and resisting powers of domestic animals usually causes indirectly a considerable death loss during unfavorable seasons. The old saying, "Poverty breeds parasites," might with at least equal truth be read the opposite way, "Parasites breed poverty."

LIFE HISTORY.

The sheep tick, being a wingless fly, is in no way directly related to the true ticks. A true tick in the adult stage has 8 legs, while the so-called sheep tick has only 6 legs and in general form and structure is entirely different. (See fig. 1.)[1] Like other insects, sheep ticks vary in size, but the average length of adult females is about one-quarter of an inch. The life cycle of the sheep tick is divided into four natural stages or divisions, namely, the egg, the larva, the pupa, and the adult or sexually mature insect.

[1] Figures 1 to 8 are from photographs by Dr. W. T. Huffman, and the picture on the title page is from a photograph by Dr. George A. Lipp.

The egg is not laid, but is retained in the body of the female, where it develops into a larva in about 7 days. At the time of birth the larva is covered with a soft white membrane, which turns brown and becomes a hard shell, called a puparium, in about 12 hours. (See fig. 2.) The term pupa applies to that stage in the life of the sheep tick from the time it is born until it hatches into a young tick. During this stage the pupa remains within its hard shell or puparium, which is attached to the wool fibers by a glue-like substance which dissolves readily in water. These shell-covered pupæ are commonly called eggs. In from 19 to 24 days from the time it is deposited the shell of the pupa is broken open at one end and the young tick emerges and becomes active in the fleece. The time between the depositing of the pupa and the emergence of the young tick is usually called the period of incubation, and its duration is influenced by the temperature. During warm weather the average period of incubation is about 19 days, while during cold weather it is about

FIG. 1.—Comparison of form and structure of sheep tick and true tick. (*a*) Sheep tick (engorged female, enlarged); (*b*) true tick (engorged female, enlarged).

24 days, and in some cases longer. However, in practical operations under average conditions, 24 days has been assumed to be the longest period.

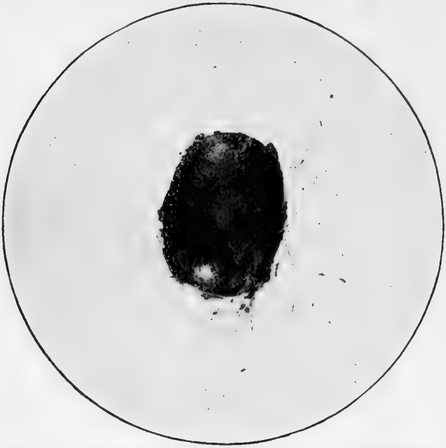

FIG. 2.—Pupa of sheep tick, commonly called the egg, taken from fleece of sheep; enlarged.

At the time the young tick emerges from the shell it is almost as large as a full-grown tick. (See figs. 3 and 4.) It develops very rapidly and reaches sexual maturity in 3 or 4 days. The female deposits her first pupa within 8 to 10 days after being fertilized.

The life history of the sheep tick, from the practical standpoint, may be summarized thus: Counting from the time when it emerges from the shell, the young tick deposits its first pupa or so-called egg in about 14 days. This pupa hatches into a young tick within 19 to 24 days. These two stages in the life history have an important bearing on the problem of eradication.

FIG. 3.—Young sheep tick emerging from the puparium; enlarged.

Dipping, if properly done, will kill all the ticks, but can not be depended upon to destroy all the pupæ. Some of the pupæ that were in the wool at the time of the first dipping will hatch, forming a new generation of ticks. This new generation must be destroyed by a second dipping before they have had time to develop and deposit pupæ. On the other hand, the second dipping should not be done before all the pupæ which were in the wool at the time of the first dipping have had time to hatch, otherwise they may hatch after the second dipping and reinfest the flock. Consequently, it is important to allow a proper interval of time between the first and second dippings if the results are to be successful. The first dipping probably destroys many of the pupæ that are less than 4 days old, and the dip remaining in the wool has a tendency to prevent the development of young ticks and probably kills many of them. Under average conditions during early fall dipping, 24 days should elapse between the first and the second dipping.

Fig. 4.—Young sheep tick just after emerging from the puparium; enlarged.

NATURE AND HABITS.

True ticks, such, for example, as the Texas-fever tick, do not pass their entire life on the animal which they infest, but always drop to the ground to lay their eggs. The life history of the sheep tick is more simple. It does not drop off the sheep to lay eggs, but deposits its pupæ in the fleece. Each female deposits an average of from 12 to 15 pupæ during her lifetime, one being laid about every 7 or 8 days. These pupæ, or so-called eggs, are attached to

Fig. 5.—Mature male sheep tick, back view; enlarged.

the wool fibers, usually from one-half inch to an inch from the skin. Consequently when the sheep are shorn the majority of the eggs are removed with the fleece.

Sheep ticks when feeding attach themselves temporarily to the skin of the sheep by burying their sucking tubes in the tissues; when not feeding they move about in the fleece. During cold, inclement weather they remain deep in the fleece close to the skin for shelter and warmth, but when the days are warm they are found near the surface and often can be seen in great numbers crawling over the tips of the wool. Sometimes they are dislodged from this position and thus temporarily infest trails, pastures, corrals, bed grounds, and premises. When dislodged from a sheep they crawl upon another at the first opportunity.

FIG. 6.—Mature male sheep tick, front view; enlarged.

The sheep tick does not transmit any known disease to the sheep, but it harbors a very small one-celled animal organism, related to forms which are transmitted by insects to various animals, including man, and which cause serious diseases.

Open-fleece sheep, such as the coarse-wool and medium-wool breeds, are subject to ravages by the tick. The fine-wool sheep usually are not affected to any great extent, as the parasites do not seem to be adapted to existence in the greasy, tight fleeces of such breeds. When the flock is heavily infested the ticks may be found on any part of the body, but they usually select locations where the wool is thin and occur in greatest numbers on those parts where they are protected from the efforts of the sheep to dislodge them. The neck, breast, shoulders, belly, and thighs are the favorite locations.

Many of the ticks are removed with the fleeces at the time of shearing, especially if machine shearing is practiced. The freshly shorn sheep offers very little protection for the ticks, and consequently, during the shearing season, the ticks migrate to the lambs in large numbers. The lambs of the flock suffer most from the ravages of this pest, and if they become heavily infested receive a setback at an important period in their development, thus causing considerable financial loss to the owner.

SPREAD.

Although sheep ticks do not seem to possess the instinct of migration to any great extent, nevertheless, once introduced into a flock, they spread rapidly until the entire flock is infested. As range sheep are usually close herded, crowded into corrals, and come into close contact on the bed grounds, the ticks pass readily from one animal to another. On farms, where the sheep are not close herded but graze in fenced inclosures, the conditions are not so favorable to rapid spreading; but during cold weather, when such sheep are placed in corrals, sheds, or barns, in close contact, every member of the flock as well as the premises will almost certainly become infested if there are ticks on any of the sheep.

While sheep ticks will not propagate or even live for any considerable time on other animals than sheep,[1] they may be harbored temporarily by dogs or other animals which have come in close contact with an infested herd. Men working among infested sheep may carry the parasites on their clothing and thus be the means of introducing them into clean flocks. If separated from the sheep the ticks do not live longer than about 4 days, as a rule, and it might be assumed that places from which all sheep had been removed would become free from sheep ticks within a very few days. However, the survival of dislodged ticks is not the only factor influencing the length of time premises may remain infested after the removal of infested sheep. Tags of wool to which pupæ are attached may be pulled out by bushes, fences, etc., or by the sheep themselves. If the weather is warm and other conditions favorable these pupæ will hatch and infest the premises.

Under ordinary conditions the period of incubation is from 19 to 24 days and in some cases longer, the length of the period being influenced by temperature and other factors. Laboratory experiments have indicated that the incubation period of pupæ removed from sheep may be as long as 46 days. Infested sheep, in their efforts to obtain relief from the irritation and itching, may dislodge some of the ticks and eggs. The ticks will die in a few days, but if conditions are favorable the pupæ or eggs will retain their vitality and hatch in due time. The pupæ dislodged from the sheep during cold weather or when the nights are frosty will not

[1] Experimental data seem to indicate that sheep ticks may live and propagate on goats. Dr. E. R. McClure placed 12 ticks on an Angora goat and held the goat under observation for 60 days. The ticks lived and propagated during this period, at the end of which time the goat was returned to the flock and observations were discontinued.

hatch, but will be destroyed. It seems reasonably certain that freezing temperature will destroy the vitality of the pupæ. These facts have an important bearing on the problem of eradication. Premises or places occupied by ticky sheep may become infested, and if conditions are favorable for the development of the pupæ they may remain infested for a period of from 45 to 50 days from the time ticky sheep were removed. A seemingly safe basis of practice during warm weather would be to consider all premises occupied by ticky sheep as infested for a period of 60 days from the date of infestation. During cold weather, when the temperature drops to freezing at any period during the day or night, infested premises probably would become free from infestation within a day or two, except in places well protected from the cold, such as sheds and stables.

During warm weather infested corrals or inclosures should not be used for clean sheep. If it is necessary to use such corrals they should be cleaned and disinfected by removing all litter and manure, cleaning down to a smooth surface, after which the floors and sides should be sprayed with a good disinfectant. The coal-tar-creosote dips diluted to double the strength recommended for dipping are suitable for this purpose. The cleaning should be done carefully in order that all pupæ may be removed with the litter, as the disinfectant probably will not destroy the vitality of the pupæ. All litter and manure from infested premises should be spread on the ground and plowed under or disposed of in such manner that sheep can not come in contact with it for at least 60 days. An economical and effective method of disinfecting stone or wire fence corrals is to scatter straw or brush over the surface of the ground and burn it. If the brush or straw is dry so it will burn readily sufficient heat will be produced to destroy the parasites.

DETECTING TICKS IN THE FLOCK.

When sheep are heavily infested with ticks they bite and scratch and rub against any available object, including other members of the flock. The natural position of the wool is disturbed by these efforts to obtain relief from the intense itching; more or less wool is pulled out, and the fleece may have a ragged appearance. (See fig. 7.)

If sheep ticks are causing the trouble, they may be found by parting the wool over the neck, breast, shoulders, belly, and thighs. They are large enough to be seen readily and are of a brownish color. On warm days they often may be observed crawling over the tips of the wool. If ticks are present pupæ usually will be found attached to the wool fibers. These are seen easily with the naked eye, being about one-eighth of an inch in length. Their color varies from yellowish white to dark brown, and the shell is glossy and firm. (See fig. 8.)

Any condition which causes the sheep to bite and scratch themselves may be mistaken temporarily for ticks. In every instance close examination should be made and the cause definitely learned. It

FIG. 7.—Lamb grossly infested with sheep ticks, showing roughened condition of fleece.

should be remembered, however, that the presence of ticks does not exclude other possible causes of the irritation, such as scab, lice, common ticks, bearded seeds, thorns, etc.

ERADICATING THE TICKS BY DIPPING.

Dipping consists of immersing the animals in a medicated liquid that will kill the parasites, and is the only practicable method known for eradicating sheep ticks. The process of dipping is shown in the illustration on the title page. In order that the medicated liquid or dip may exert its killing powers it is necessary that it come in direct contact with the tissues of the parasite. There are three methods by which the dip may enter the organism of the tick; first, ingestion, by way of the mouth parts, through the digestive organs; second, respiration, by way of the stigmata or breathing pores, through the respiratory organs; third, absorption, through the skin by a process of osmosis. The nonvolatile dips, such as the arsenic group, are probably taken in largely by ingestion and to a less extent by absorption, and kill through cumulative action of the poison. The nicotin dips are probably taken in mainly by absorption and to a less extent by ingestion and respiration. The coal-tar-creosote and cresylic-acid dips give off gases and are taken in mainly by respiration and possibly to a less extent by absorption. It is seemingly not a mere question of bringing the parasite into temporary contact with the dip, as the period of time during which the poison exerts its action is an important factor. Very few of the known dips will kill the parasite immediately; therefore the length of time the sheep are held in the vat is not the sole determining factor, provided they are held in the dip a sufficient length of time to saturate the fleece. The length of the wool, the quantity of dip retained in the fleece, the length of time that the dip remains active in the wool, and the nature

FIG. 8.—Close view of portion of neck of lamb shown in figure 7, showing ticks and pupæ in wool.

of the active principle, all have an important bearing on the results. Other factors being equal, the dip that remains longest in the wool and retains its killing power for the longest period is most desirable, not only for destroying the parasites on the animal but also for preventing reinfestation.

In dipping sheep for ticks the entire flock, together with all goats, dogs, or other animals which may have been with the sheep, should be dipped regardless of the number showing infestation. The fleece should be saturated thoroughly, but as there are no crusts or scabs to be penetrated, it is not necessary to hold the animals in the vat longer than about 1 minute. The head of each animal should be submerged at least once and care taken that every part of the fleece is wet. As only coarse-wool and medium-wool sheep usually become infested heavily, and as such fleeces are penetrated easily by the dip, it is not considered necessary to maintain the dip at a high temperature. However, it should not be cold enough to chill the animals; the range should be between a minimum of 65° F. and a maximum of 95° F. The temperature of the dip should be ascertained accurately by using a thermometer. If a proprietary dip is used the printed instructions on the label of the container should be followed both as to the time the animals are to be held in the dip and the temperature at which the dip is to be used.

The season best suited for dipping to eradicate ticks depends upon the altitude, the climatic conditions, and the methods of handling the sheep. In those sections where spring shearing is practiced, July and August are considered the best months for dipping. If the lambs become heavily infested shortly after shearing, which often occurs, the flock should be dipped as soon as the shear cuts heal. One objection to dipping too soon after shearing is that the wool is short and the fleece will not retain much of the dip. For this reason fall dipping probably would prove more effective than summer dipping in eradicating ticks. It is advisable, however, to dip at about the same time that the neighboring flocks are dipped in order to lessen the chances of reinfesting the neighborhood.

If the dipping is to be successful, it is necessary to give close attention to the details and to see that the work is performed carefully and thoroughly. Sheep should not be dipped immediately after shearing; a period of at least 10 days should elapse between shearing and dipping, in order that the shear cuts may heal. It is dangerous to dip sheep in some of the dipping preparations if there are any fresh wounds on the animals; consequently, dogs that bite the sheep should not be allowed in the dipping corrals. The chutes, pens, and dipping vat should be examined closely for nails, broken boards, or any object that may puncture or wound the skin of the sheep. Animals having fresh wounds when dipped in some of the dips usually develop a condition commonly known as "blood poisoning," and the mortality from this cause is high. After the wounds have granulated or healing is well started there is little or no danger from this source. Rough handling of the sheep at the time of dipping results in more harm and damage to the flock than is caused by the dip. When sheep are placed in the dipping vat by hand, the men handling them should be instructed to do so carefully. They should not be allowed to catch the sheep by the ears; this is sometimes done, and has resulted in breaking or bruising the skin, causing the heads to swell after dipping, and resulting in considerable death loss.

Ewes and lambs should not be dipped together; if put into the vat at the same time the danger of drowning some of the lambs is much greater than when they are dipped separately. The lambs should be "cut out" and dipped separately, and they need not be held in the swim as long as the older sheep. It has been stated that the ewe recognizes her lamb more readily when they are dipped together; this, however, is probably not correct. A ewe recognizes her lamb by smell and not by sight, consequently after the flock has been dipped and the ewes and lambs have been turned in together there is considerable commotion for a time, as the ewes fail temporarily to recognize their offspring. However, the members of the flock will adjust matters for themselves, and, as a rule, practically every lamb will be recognized by a mother. It often happens that an undipped sheep will jump out of the pens and get in with those that have been dipped. This should be carefully guarded against and all such sheep dipped before the flock leaves the vat.

Prior to bringing the sheep to the vat for dipping they should be watered and fed so as not to be thirsty or hungry at the time of dipping, although they will probably stand the effects of dipping better if not too full of feed and water at the time dipped. If they are watered and fed 3 to 6 hours before dipping they are likely to be in the best condition for the operation. When the weather is cold or stormy dipping operations should be commenced early in the morning and finished for the day in time to give the last sheep dipped opportunity to dry off before night. During winter weather dipping for the day should be finished by noon, so that the flock may have time to dry off and fill up with feed before night, as a sheep with a full stomach will withstand much cold and hardship. If these precautions are observed sheep may be dipped with reasonable safety during cold weather.

Bucks should be dipped separately from ewes and lambs. They should not be driven fast and then put into the vat before resting and cooling off. As they succumb very easily in the vat, it is necessary to give them careful attention. At the large vats the buck herds usually are dipped first, while the vat is full, so as to afford them more swimming room.

DIRECTIONS FOR DIPPING.

The quantity of dip in the bath should be sufficient to submerge the sheep completely; that is, the depth of the dipping fluid in the vat should be not less than 40 to 48 inches, depending on the size of the sheep. The quantity of fluid necessary to fill the vat to the required depth should be ascertained before it is prepared. Freshly shorn sheep and short-wool lambs will carry out on an average from 1 to 2 quarts of dip, depending on the size of the sheep and the length and grade of wool, while full-fleeced, fine-wool sheep will carry out and retain in the fleece as much as 2 gallons. At late fall dipping the average medium-wool sheep will retain in the fleece about 1 gallon of dip. In estimating the quantity of dip required, these facts should be taken into consideration. After computing the quantity of dip required to charge the vat, the average quantity which each sheep will carry out should be estimated; this should be multiplied by the number of sheep to be dipped, and the product so obtained added to the quantity required to fill the vat. If the vat and draining pens are water-tight, so that no dip is lost through them, the total as given above should show the approximate number of gallons of dip required to complete the work.

FIG. 9.—Stirring plunger for mixing liquids in the vat.

After the vat is filled to the required capacity the contents should be well mixed by stirring, in order that the temperature may be uniform throughout. A good method of stirring the dip in large vats is to take a 5-gallon pail or dip container, punch holes near the top, insert a wire for a bail, allow the can to fill and partially sink, then drag it with a dipping fork rapidly from one end of the vat to the other, and repeat the process until the temperature is uniform, as shown by taking it at several points in the vat. Stirring plungers are useful implements, and, as they are easily made, one or more should be provided at every vat. They are used in a manner similar to the movement of the dasher of an old-fashioned hand churn. The plunger is pushed to the bottom of the vat and raised rapidly, the process being repeated as the operator moves slowly along the vat. The style shown in figure 9 is the one most commonly used.

The dip should be changed as soon as it becomes filthy, regardless of the number of sheep that may have been dipped in it. In emptying the vat the entire contents should be removed, including all sediment and foreign matter. After the liquid portion has been dipped out or drained off, the sediment and dirt at the bottom should all be removed and the bottom cleaned by sweeping or scraping with a hoe or spade. After lime-sulphur-arsenic dip has been mixed to the proper strength for dipping and used in the vat, it should not be used again after it is 10 days old. This is a safe rule to follow with any of the sheep dips, as losses often occur from dipping in old or stale dips.

The drowning of sheep in the vat can be avoided by proper care. Men with dipping forks should be stationed along the vat on both sides to attend the sheep and prevent accidents. When the vat becomes filled with sheep their progress is retarded and they frequently attempt to raise themselves out of the dip by placing their forefeet on the back of the sheep in front. The men along the vat should prevent this by keeping the sheep properly arranged in the vat. The dipping forks should be used to keep all of the sheep's body submerged except its head while it is passing through the vat; this can be done by placing the dipping fork over the shoulders of the sheep and gently but firmly pushing it under the dip. The animal will raise its nose so that the neck and part of the head can be submerged without danger of strangling. Old ewes that have been dipped a number of times are sometimes difficult to handle, both in the chutes and in the dip. They will often lie on their sides in the vat, bracing themselves with their feet against one side and their backs against the other. When pushed under they will make efforts to regain this position and may strangle. Sheep that are affected by eating loco weed often drown in the vat unless they are piloted through. When strangling occurs the sheep should be taken from the vat. If it does not get upon its feet, pull the tongue forward, dash cold water over the head and body, and if necessary, induce artificial respiration. When it has regained sufficient strength, and if it has not been in the dip long enough, the animal should be returned to the pens and piloted through the vat again.

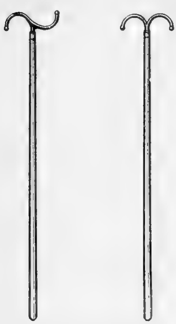

FIG. 10.—Two styles of dipping forks.

DIPPING FORKS.

In using large vats dipping forks are necessary for the efficient handling of the sheep and should be provided as a part of the equipment at every plant. Several different styles are made, but the two shown in figure 10 are the ones commonly used. The one with both hooks turned upward seems to have the preference for the reason that when it is in use either side may be hooked under the neck of the sheep for raising the head in case of strangling. The handles should be strong and from 5 to 6 feet long. The hooks should be made of half-inch round iron and firmly held in the handle by an iron ferrule. These forks can be bought ready-made or may be made by any blacksmith.

EXPENSE OF DIPPING.

The cost of dipping naturally varies in different sections; it also varies in the same section, depending on the number of sheep to be dipped, the location relative to the necessary supplies, and the facilities available for the work. The labor, fuel, and cost of materials are the three principal items of expense. In the sheep-growing sections of the West the average cost of dipping sheep varies from 2 to 3½ cents a head for each dipping.

WATER FOR DIPPING PURPOSES.

Water is so good a solvent that it dissolves and holds in solution large quantities of the various mineral salts. Waters containing such salts are commonly spoken of as being "brackish," "hard," or "alkali," depending upon the amount and character of the mineral matter contained. Much of the water on the semiarid ranges of the West is hard or alkaline and not suitable for diluting all kinds of dips. The thickly settled farming communities, being located in areas of greater rainfall, do not experience so much difficulty in finding a supply of reasonably good water. However, hard or alkaline waters are found more or less frequently in all parts of the United States, and where it is possible to do so their use for dipping purposes should be avoided for two reasons: First, to lessen the possibility of injury to animals; second, to increase the wetting powers of the dip and consequently the curative effects.

The wetting power of a dip is influenced by several factors, but observations indicate that when soft water is used for diluting dips the fluid has greater wetting power than when some of the hard waters are used. The term "beading" is commonly used in connection with dips of low wetting power. Such dips have a tendency to form in small bead-like drops over the wool instead of spreading in a film around each wool fiber and becoming evenly distributed over the entire exposed surface. By increasing the wetting power of the dipping fluid its efficiency is enhanced, because the active principle is more evenly distributed and all exposed parts receive the maximum possible wetting. Experience has demonstrated that good dips sometimes are rendered ineffective by being diluted with alkaline water.

Before diluting coal-tar-creosote or cresol dips with hard or alkaline water, a test should be made to determine whether a separation occurs in such water. In a clean bottle or jar of clear glass place a measured quantity of dip, and pour in, with thorough mixing, the desired quantity of the water, preferably warm, which should be added in approximately the proportion to be used in dipping. If after standing for one hour an oily layer or mass of globules appears either at the top or at the bottom of the liquid, the dip should not be used with that kind of water.

Sheep dips are most effective when used with soft water. If it is necessary to use alkaline water for diluting such dips, the water may be "broken" by using sal soda in the proportion of from 1 to 4 pounds for each 100 gallons of water, depending upon the "hardness" of the water. Where the water intended for dipping purposes is very impure the owner should have it analyzed and obtain the advice of a competent chemist on methods of correcting the water to render it suitable for diluting the dip he proposes to use.

KINDS OF DIPS.

In choosing a dip for sheep ticks the conditions under which it is to be used should be considered. A dip that might be best under one set of conditions is not necessarily so under all conditions. The nature of the dip and its effect on the animals when used with the water available at the dipping plant should be considered. If the dipping plant is not supplied with soft water the dip that works best in the water available should be selected. Dips deteriorate by use; that is, after a number of sheep have passed through the vat the active principle of the dip falls below the standard required for effective work. For example, during investigations in the Bureau of Animal Industry 35 lambs in 4 groups were dipped in a vat containing 60 gallons of diluted cresol U. S. P., 1 part to 100 parts of water. Samples were taken before and after dipping each group. These samples were analyzed, with the following results:

	Per cent cresylic acid.
No. 1, taken before any lambs were dipped	0.45
No. 2, taken after 9 lambs were dipped	0.34
No. 3, taken after 18 lambs were dipped	0.26
No. 4, taken after 27 lambs were dipped	0.18
No. 5, taken after 35 lambs were dipped	0.12

The difficulty has been overcome for some of the dips, and the Bureau of Animal Industry now supplies its inspectors with portable testing outfits for testing the dip at the vat. The only dips for which portable testing outfits are available at present are the arsenic, the nicotin, and the lime-sulphur.

Certain groups of ready-prepared dips are efficacious and have been used by flock owners with a fair degree of success. Among these may be mentioned the coal-tar-creosote, the cresol, and the nicotin dips. The only homemade dip which has proved efficacious is the lime-sulphur-arsenic dip. This dip probably will eradicate sheep ticks with one dipping when all conditions are favorable, but one dipping can not be depended upon in practical operations. It will undoubtedly eradicate ticks if the flock is given two dippings, and it has the advantage that it may be used in almost any of the hard waters without injury to the animals from that cause. Its disadvantages are that there is no test by which the rate of deterioration may be determined in the field and that it is more difficult to prepare than some of the other dips. None of the dips tried in the bureau's investigations can be depended upon to eradicate sheep ticks with one dipping.

COAL-TAR-CREOSOTE DIPS.

The coal-tar-creosote dips are sold under a large number of trade names. They are made from coal-tar derivatives and the principal ingredient is so-called creosote oil, which is made soluble in or miscible with water by means of soap. When diluted with suitable water they are very efficacious in eradicating sheep ticks from a flock if two dippings are given with an interval of 24 to 28 days between dippings. There is no field test for determining the deterioration of these dips, and consequently in replenishing the dip the percentage of active principle in the vat is largely a matter of guesswork.

These dips should contain, when diluted ready for use, not less than 1 per cent by weight of coal-tar oils and cresylic acid. In no case should the diluted dip contain more than four-tenths of 1 per cent nor less than one-tenth of 1 per cent of cresylic acid; but when the proportion of cresylic acid falls below two-tenths of 1 per cent the coal-tar oils should be increased sufficiently to bring the total of the tar oils and the cresylic acid in the diluted dip up to 1.2 per cent by weight.

In the undiluted coal-tar-creosote dips, especially in cold weather, a separation of naphthalene and other constituents of the dip may occur. Care should therefore be taken to see that the dip is homogeneous in character before using any portion of it.

CRESOL DIPS.

The cresol dips are sold under various trade names, and consist of a mixture of cresylic acid with soap. The term cresylic acid as used in this connection covers those cresols and other phenols derived from coal tar, none of which boil below 185° C. (365° F.) nor above 250° C. (482° F.). When diluted ready for use a cresol dip should contain one-half of 1 per cent of cresylic acid. As there is no field test available for cresol dips, the rate of deterioration can not be determined at the vat, and consequently after a few sheep have been dipped there is no method known for keeping constant the percentage of cresylic acid in the used dip.

When used with suitable water these dips are very efficacious in eradicating sheep ticks, if the flock is given two dippings 24 to 28 days apart.

Coal-tar-creosote and cresol dips should always be tested on a small scale, as outlined on page 17, to avoid injury to the sheep as far as possible. However, death losses may occur even when there is no apparent separation in the dips when tested under this method. Special care in this connection is necessary where hard water is used.

NICOTIN DIPS.

The nicotin dips are sold under various trade names, and the flock owners are more or less familiar with them from use in dipping for scabies. When used in seven-hundredths of 1 per cent solution they will eradicate sheep ticks, if two dippings are given with an interval of from 24 to 28 days between dippings. A field test has been designed by one of the large manufacturers of nicotin dips so the percentage of nicotin in the dip may be ascertained at the vat side at any time. These dips should be used in accordance with the instructions printed on the label of the container.

THE LIME-SULPHUR-ARSENIC DIP.

The lime-sulphur-arsenic dip is made by mixing standard strength lime-sulphur dip with one-half standard strength arsenical dip. Directions for making lime-sulphur dip and the arsenical dip and mixing the two to form a dip for sheep ticks are as follows:

The lime-sulphur dip is made in the proportion of 8 pounds of unslaked lime (or 11 pounds of commercial hydrated lime, not air-slaked) and 24 pounds of flowers of sulphur or sulphur flour to 100 gallons of water. Place the lime in a water-tight, shallow box and add sufficient water to form a thin paste. Sift the sulphur into this and mix well until a paste of about the consistency of mortar is formed, adding water as required. Place this lime-sulphur paste in 30 gallons of boiling water and boil for 1 hour, adding water from time to time to maintain the quantity at 30 gallons or in that proportion. During the boiling process the mixture in the boiling tank should be stirred well to prevent the paste from settling and caking on the bottom of the tank; the boiling process should be continued until all sulphur disappears from the surface. A large mortar hoe is a good implement with which to stir the boiling mixture. The lime and sulphur should both be weighed; do not trust to measuring them in a pail or guessing at the weight. It sometimes happens that the sulphur is not all "cut" or dissolved; this is especially true if the lime is not of first-class quality. Small quantities of extra lime may be added if during the cooking it is noted that the sulphur is not being "cut" properly. As an excess of lime in the dip will tend to injure the sheep and the wool, no more lime should be added than is necessary to cut the sulphur. After the mixture has been boiled for 1 hour the liquid should be of a chocolate or dark amber color.

The contents of the boiling tank should be drawn off or dipped out and placed in the settling tank and allowed to stand until all sediment has settled to the bottom and the liquid is clear. The use of some sort of settling tank provided with a bunghole is an absolute necessity, unless the boiler is so arranged that it may be used for both boiling and settling. An ordinary water-tight barrel will answer very well for a settling tank at small vats. All settling tanks of every nature should have an outlet at least 4 inches from the bottom, in order that the clear liquid may be drawn off without becoming mixed with any of the sediment (see fig. 11). Drawing off the liquid as above indicated has an advantage over dipping it out, for the reason that in the latter case the liquid is stirred more or less and mixed with the sediment. The prime object is to get the clear liquid without any sediment. The sediment should under no circumstances be allowed in the dipping vat, as it will injure the wool and the eyes of the sheep.

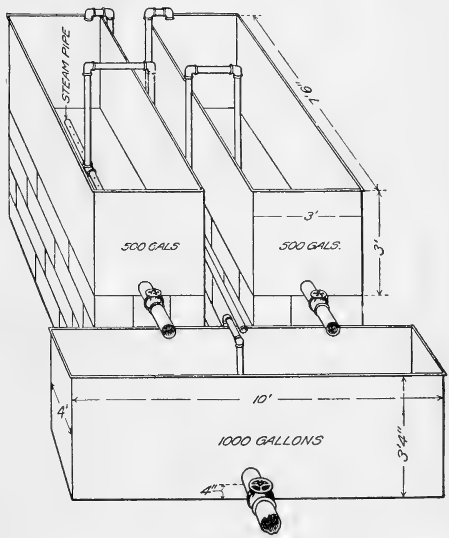

Fig. 11.—Cooking and settling tanks.

When the sediment has fully settled, draw off the clear liquid into the dipping vat and add warm water sufficient to make a total of 100 gallons of dip. When mixed and cooked as above specified the concentrate is three and one-third times the strength required for the dip in the vat, so that to every 30 gallons of such concentrate 70 gallons of warm water should be added to make a dip of the required strength.

In preparing lime-sulphur dip in large quantities, several hundred gallons of concentrate are often made at one time in a single large cooking tank. The quantity made at one boiling is limited only by the facilities at hand. If the boiling tank is of sufficient capacity enough lime-sulphur paste should be cooked at one time to dip the flock. The quantity of mixture in the cooking tank may be varied at will, but the proportions of the various ingredients should not be altered.

To each 500 gallons of lime-sulphur solution prepared and diluted as above directed add 4 pounds of arsenic[1] and 12 pounds of sal soda made into a solution as follows: Put 12 gallons of water in a kettle or tank, heat to boiling, and add 12 pounds of sal soda; when this has been dissolved add 4 pounds of powdered white arsenic, then boil and stir for 15 minutes or longer, until the white arsenic has entirely disappeared. The quantity of arsenical solution prepared at any one time is limited only by the capacity of the kettle or tank, but the proportions of the ingredients should not be altered. The arsenical solution should be added to the diluted lime-sulphur solution in the vat. When the arsenical solution is added a yellow-colored flocculent precipitate is formed which remains in suspension. The liquid in the vat should be well stirred before dipping operations are commenced. This dip can be used in any kind of water without injury from the water, but there is no field test for its strength.

It should be remembered that this dip is poisonous, and due precaution should be taken in handling and using it. The sheep should be held in the draining pens and holding corrals until all surplus liquid has drained from the fleeces. When the vat is emptied the dip should be disposed of in such manner that the animals may not have access to it. Preferably it should be run into an inclosed pit.

INJURY FROM DIPPING.

Dipping often results in a slight setback to the sheep. There may be a temporary shrinkage in weight or constitutional disturbances, or both. Various factors operate to produce these conditions. They may occur with any of the standard dips, but should not always be attributed to the effects of the dip alone. The age and physical condition of the sheep, the method of handling the flock at the vat as well as before and after dipping, the character of the water used, the method of preparing the dip, and various other factors should be considered before placing the blame on the dip. Young animals in a thriving condition recuperate very rapidly from any temporary ill effects; while old, weak, or emaciated animals succumb very readily and regain lost weight slowly. Injury caused by dipping is more likely to result from improper methods of dipping and handling than from the direct effects of the dip. Rough handling of sheep in the corrals and legging pens; dipping the flock immediately

[1] Farmers' Bulletin 603 contains directions for making arsenical dip.

after a long, hard drive before they have rested and cooled off; dipping late in the afternoon when the nights are cold; keeping the sheep without feed and water for long periods before and after dipping; using dogs in the corral; and fighting stubborn sheep to get them into the chutes, are some of the contributing causes of injury. However, some of the dips if used in unsuitable water may cause injury, and any of them when used too strong will injure the sheep.

The question often arises as to the proper age at which lambs should be dipped to get the best results and cause the least damage. It is perfectly safe to dip the flock when the lambs are not less than 1 month old, provided the lambs are dodged out and dipped separately. Any slight shrinkage caused at this time will be regained quickly and the lambs will grow and thrive much more rapidly after being freed of the irritation caused by the ticks. If the work is done properly and the sheep handled carefully, pregnant ewes may be dipped with safety at any time up to within one month of lambing.

DIPPING PLANTS.

EQUIPMENT FOR SMALL FLOCKS.

The farmer who has but a small flock to dip can use a portable galvanized-iron vat as shown in figure 12, turning a part of his barnyard or sheds into catch pens for temporary use. The portable galvanized-iron dipping vats, called "hog vats," can be purchased ready-made and will answer

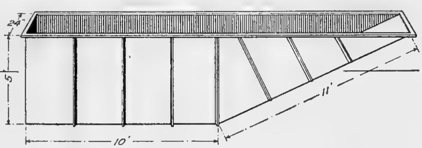

FIG. 12.—Portable galvanized-iron sheep dipping vat.

the purpose very well for dipping small lots of farm sheep. They are sometimes set on the surface of the ground and the sheep lifted into them, but this method is not very satisfactory. An excavation should be made, the dimensions of which exceed slightly the outside dimensions of the vat, except the depth, which should be less, so that when the vat is set in the trench the top may extend about 6 inches above the surface of the ground. Approaches and draining and holding pens may be provided as desired.

A canvas dipping bag (fig. 13) is used sometimes when only a few sheep are to be dipped at different points in a given section, as it has the advantage of being easily transported. It is made of heavy canvas, known in the trade as No. 40, and is constructed as follows: Two strips of canvas 8 feet long and 26 inches wide are sewed together to form a bag 48 inches deep and 94 inches in circumference. Seams are triple sewed and top and corners reinforced with leather strips riveted on. Iron rings held by leather ears are riveted to the upper part of the bag as shown in the illustration. The bag is filled with dip, diluted as for use in a dipping vat, the sheep's feet are tied, and the animal is set down in the bag and held the required length of time.

Heating tanks or boilers are necessary, the size varying with the number of sheep to be dipped. An ordinary iron caldron or kettle will answer the purpose for a small number of sheep. A rectangular galvanized-iron tank with large heating surface is preferable. Such a tank is set on two parallel walls, the walls forming the sides and the bottom of the tank forming the top of the fire box. An opening large enough for the escape of the smoke should be provided at the end opposite that at which the fire is fed.

FIG. 13.—The canvas dipping bag in use.

A PERMANENT DIPPING PLANT.

When large flocks are to be dipped or when a farmer is in the sheep business permanently, it is necessary to provide proper facilities for the work and a permanent dipping plant is the only practical solution. It should be constructed and equipped so that it will be suitable for use in dipping sheep for scab as well as for ticks and other parasites.

SELECTING A LOCATION.

In selecting a location for a dipping plant the fact that sheep work better upgrade should be considered and, if possible, the ground used for the receiving corrals and chute should slope up to the end of the vat. The vat itself should be on level ground and preferably extend north and south, with the entrance at the south and the exit at the north, as it has been observed that sheep work better also when not facing the sun. If the ground selected has good natural drainage, it is a point in favor of the location.

CORRALS AND CHUTES.

In constructing a dipping plant the arrangement of the corrals is important. The receiving corrals, into which the sheep are driven preparatory to dipping, as well as the holding corrals, into which they go from the draining pens, each should be large enough to hold a full band of sheep, or about 3,000 head. The receiving corral should be constructed so that there may be the least practicable number of corners or places in which the sheep may become jammed or "piled up."

In an effort to get out a sheep will try to go back to the place where it entered the corral; therefore, if the entrance gate is near the vat the herd will tend to crowd toward the vat and thus save considerable work in getting them into the chute or catch pen. The corrals and chutes may be so arranged that a combination legging pen and running chute is provided. Sheep usually work well in a chute the first time they are dipped at a vat, but in the case of old ewes that have been dipped several times at the same vat it is often necessary to put them into the vat by hand. The location and arrangement of the chutes are sometimes changed from year to year so the sheep may not recognize them so readily. The running chute should be curved to obstruct the view, and the side on which the men work should be tight-boarded. The usual height for the sides of the chute is 40 inches, and the width of the chute 18 to 22 inches, depending on the size of the sheep. Sheep work well uphill but not down an incline; the chutes and alleys, therefore, should be upgrade to the vat. If necessary, elevate the running chute so that it slants upward to the slide board. A small pen should be provided near the entrance to the vat and so arranged that the sheep may see it. This pen, known as a "decoy pen," is filled with sheep to induce the other members of the flock to work toward the vat more readily in their efforts to join those in the pen. The size and arrangement of the corrals will vary necessarily with the topography of the location and the individual ideas or tastes of the owner.

DRAINING PENS.

When a sheep emerges from the vat it carries out a large quantity of dip in the fleece. Most of this dip drains out of the fleece very rapidly, and it is desirable that it be saved and returned to the vat. Draining pens with water-tight floors sloping toward the vat, therefore, should be provided. The size will depend upon the size of the plant and the number of sheep to be dipped. The relative size shown in the plans illustrated in figures 14 and 15 may be followed, increasing or decreasing the size of the pens to correspond to the length of the vat. There should be two draining pens, each having an opening into the holding corral. They may be made of lumber or cement and should have catch basins or screening and settling wells into which the dip drains so as to prevent manure and foreign matter from being carried into the vat. Drawings of screenings and settling wells will be found in the plan of the cement dipping plant (fig. 15). In constructing draining pens of cement it is advisable to build the outer walls in the same manner as the foundation for a house, except that they are to be 6 inches thick. The space inside these walls is then filled with gravel to the required height and the floor laid on it. Cement floors should have rough surfaces to prevent slipping. A coat of "pebble dash" over the cement floors will afford a suitable surface for the sheep to stand on, or the cement surface, while soft, may be roughened by means of a stiff broom. The floors of draining pens should slope so that the dip will drain away rapidly and not collect in pools from which the animals may drink.

VATS.

The dipping vat may be constructed of either lumber or cement, the cement vat being preferable. The length of the vat may vary from 30 to 100 feet, depending on the number of sheep to be dipped. Public dipping vats, where from 50,000 to 100,000 sheep are dipped each season, should be 100 feet long. The depth should be 5 feet, width at bottom 8 inches and at top 2 feet. Sheep vats usually are constructed so that the top is flush with the top of the ground, and there should be no crosspieces to interfere with the free action of the sheep or of the men working along the vat. As a matter of individual taste, however, the top of the vat may extend from 9 to 18 inches above the ground. Those of the latter kind afford a better opportunity to handle the sheep and can be operated with less effort than those whose top is flush with the ground. If it is desired that the top of the vat should be flush with the ground, it should first be built at least 4 inches above the natural surface of the ground and then dirt or gravel may be filled in, thus securing proper drainage along the sides.

Whenever it is possible to do so the gravity method of draining the old dip out of the vat should be adopted, as otherwise it is necessary to pump or dip it out each time the vat is cleaned. The end of the vat having the drain should be slightly lower than the other end so that all the liquid will drain off.

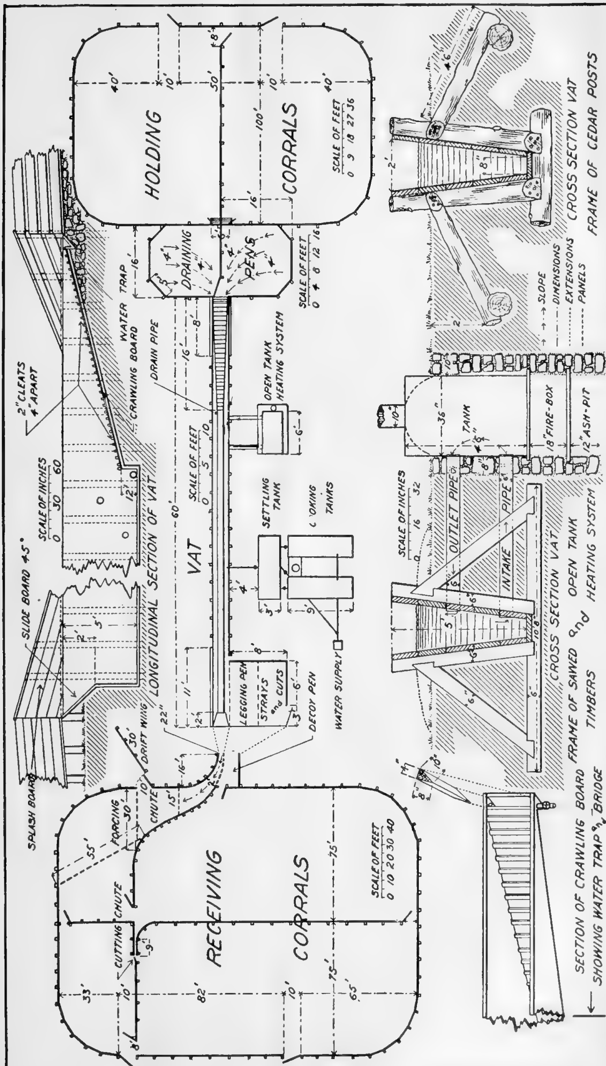

Fig. 14.—Plan of sheep-dipping plant; wooden vat.

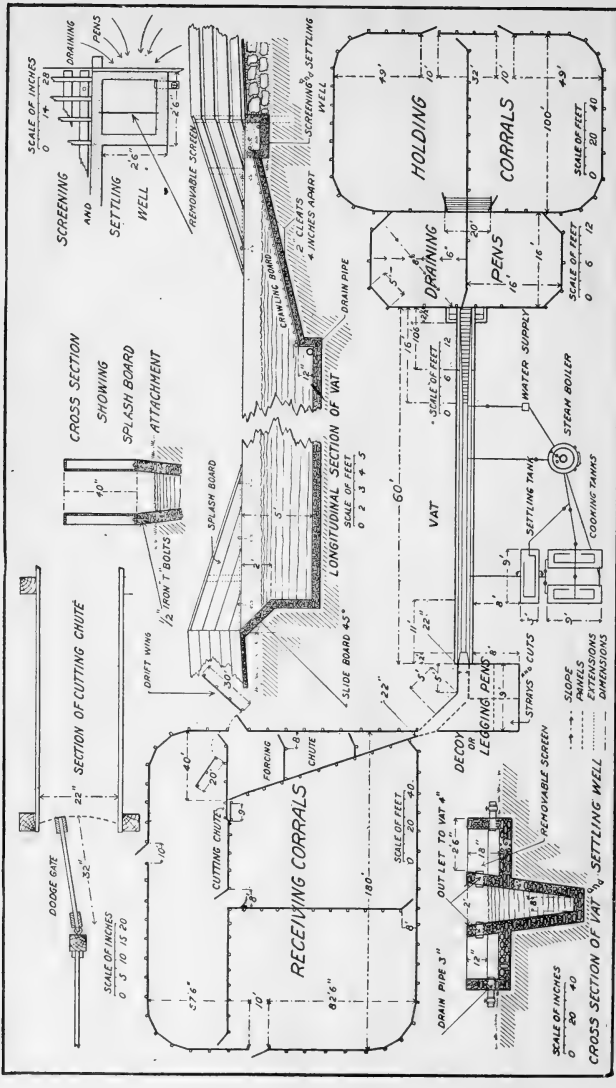

FIG. 15.—Plan of sheep-dipping plant; cement vat.

The slide board into the vat should be set at an angle of 45 degrees and extend from the floor of the chute to at least 4 inches below the dip line; it should be made of or covered with a smooth-surfaced material, such as planed lumber or sheet metal. The end extending into the dip should be flush with the vertical end of the vat. A space between the slide board and the end of the vat, if large enough for a lamb to lodge in, is a dangerous arrangement. The runway leading out of the vat should not be too steep. The length varies from 8 to 16 feet, the latter being preferable in large vats.

HEATING FACILITIES.

When lime-sulphur dip is used it is necessary to provide cooking tanks. The cooking may be done by steam or in open boilers having a fire box under each. All large plants should have steam boilers of not less than 25 horsepower. The live steam can be piped into the dipping vat and used for maintaining the temperature of the dip and also into the cooking and heating tanks for boiling the dip or heating water. The steam pipes should extend along the floor of the vat at least two-thirds of the length and be provided with openings for the escape of the steam into the dip. The supply pipe from the settling tank should enter the vat above the dip line in order that any leak may be detected easily. The open-tank heating system, if preferred, may be installed instead of the steam boiler.

CARE OF PLANT WHEN NOT IN USE.

A dipping plant that does not receive proper care when not in use deteriorates very rapidly. The pressure of the ground against the sides of the vat tends to cause them to bulge inward; this tendency may be counteracted to some extent by keeping the vat full of liquid. Wooden vats which are allowed to stand empty will dry out, and the lumber will shrink so that the vat will leak when refilled. At the close of dipping operations the vat should be left full of liquid and water added from time to time to restore that lost by evaporation.

A week or 10 days prior to beginning dipping operations the entire plant should be overhauled and put in good condition. Before charging a new vat or one which has stood empty for some time, it should be filled with water to ascertain whether it leaks.

CONSTRUCTION OF DIPPING PLANTS.

Plans for construction of wooden and cement sheep-dipping plants are shown in figures 14 and 15. They are not drawn to a uniform scale, consequently in studying the drawing the scale of each part should be noted. The plants as shown have no superfluous equipment, and the arrangements are as simple as is consistent with efficiency. The size of the plant can be increased or decreased as desired. A different corral, chute, and legging pen arrangement is shown with each vat. All these parts are suitable for use with either vat. Cross fences as desired can be added to the corrals. Cutting chutes are shown in both plans, as every large dipping plant should have such a chute equipped with a dodge gate so the lambs may be cut out and dipped separately.

If permanent pipes are used for conducting water and dip to the vat they should be laid so as not to act as an obstacle to the men working along the vat. There should be no obstructions to the path along both sides of the vat. The pipes can be placed under the ground, or a portable V-shaped trough can be used for conducting liquids into the vat and laid aside when not in use.

THE WOODEN VAT.

As shown in the plans for the wooden vat, one side of the running chute is made of portable panels so they may be shifted and the space converted into a legging pen. Two styles of framing are shown. In the cedar-growing sections the cedar-post frames are preferable because they do not decay rapidly, while the sawed white-pine timbers do. Where hardwood is used instead of white pine the frame timbers need not be so heavy; 4 by 4 inches is heavy enough for framing in hardwood. The frames are set from 2½ to 4 feet apart, depending on the character of the soil and the material used; 2½ feet apart is a safe rule, as the closer the frames are to each other the less tendency there is for the sides of the vat to bulge in between the frames. Two-inch tongue-and-grooved planks should be used in making the vat, and they should be beveled so all joints and seams may be properly calked with oakum or similar material.

The open-tank heating system is shown in the drawings. When this system of heating is used it is not necessary to have settling wells, as the heating tank acts as a settling well. It has an advantage over the old-style coil-heating system in that the pipes are easily cleaned if they become clogged. A water trap is provided for in the exit end of the vat with a bridge to fit into the trap while dipping is being done. When dipping operations are finished for the day the bridge should be removed and the valves of the drainpipes opened so water from the draining pens may not run into the vat.

THE CEMENT VAT.

In the plan for the cement plant the corrals and chute are very conveniently arranged. The portable panels can be shifted to form either a running chute or a legging pen. The settling and screening wells shown also can be constructed as a part of any vat by changing the slope of the draining pens so the dip will run into the wells instead of down the runway. In making the forms for a draining well, the groove into which the removable screen is to sit should be provided for, as well as the 4-inch openings for drain and outlet pipes.

The trench for a cement vat should be excavated so that the inside dimensions correspond with the outside dimensions of the vat when completed. If the sides of the trench are smooth and reasonably firm they can be used as the outer wall of the form, but in all cases where the vat is extended above the surface of the ground it is necessary to build forms extending from the surface of the ground to the top of the vat. If the soil is sandy it will be necessary to build outer forms, in which case the trench should be wide enough to allow for these forms. The drain and other pipes shown in the drawing should be placed in the form and should all be threaded and capped so that proper connections may be made. The ½-inch iron bolts and the iron pipe shown in the drawings should be embedded in the cement of the incline for attaching the false floor or crawling board. The floor is made of 1 by 6 inch boards laid lengthwise with cross cleats as shown in drawings. The splashboards at the entrance end of the vat and the guides at the exit end are nailed to 2 by 4 inch scantling bolted to the cement wall, and the bolts should be embedded when the wall is being constructed. Two pairs of bolts should also be embedded for attaching the slide board. Steam pipes should not be molded into the concrete walls, as the vibration of the pipes will crack the cement. They should pass over the top of the vat and down the side in a groove formed in the wall, so they will not come in contact with the sheep or cause annoyance to the men working along the vat.

The walls should be made 6 inches thick, constructed of concrete mixed in the proportion of 1 part cement, 2½ parts sand, and 4 parts broken stone or gravel. This mixture is slushed into forms properly set, and when it approaches dryness the forms are removed and the inside surface of the vat coated with pure cement mixed to about the consistency of cream and applied with a brush. It is important that this coating be well brushed in so as to fill all cavities and form a smooth surface. Finishing coats of sand and cement applied with a trowel after the forms have been removed are liable to crack and scale off.

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CARBON DISULPHID AS AN INSECTICIDE

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CHEMICALLY pure carbon disulphid is a colorless watery liquid formed by the union of two elementary particles of sulphur with one of carbon. Its chemical symbol is therefore CS_2. The name is spelled in several ways: Disulphid, disulphide, bisulphid, and bisulphide. The colloquial name most frequently used appears to be "high life."

This bulletin gives the necessary facts regarding the nature of carbon disulphid and the general principles involved in the safe, economic, and effective use of this valuable insecticide. It is a revision of Farmers' Bulletin 145, which it replaces, but it includes new information based to a large extent on work conducted by the author at the Alabama Experiment Station and published here with the approval of the director of that station. The bulletin is adapted to all parts of the country.

CARBON DISULPHID AS AN INSECTICIDE.

CONTENTS.

INSECT PESTS WHICH MAY BE KILLED BY CARBON DISULPHID.

Carbon disulphid is a liquid which evaporates quickly when exposed to the air, forming a heavy inflammable vapor having great penetrative power so that it is very useful in destroying insect pests. This substance is used most extensively to kill weevils and other pests that injure stored grains, beans, cowpeas, and peas, but it may be employed with advantage to kill many other kinds of insects. These may be arranged in three groups. In one group are species that live underground on the roots of plants or that nest in the ground, as do some aphids, the white grubs, mole crickets, ants, and others; in the second group are species that attack various stored products, such as grain insects, pea weevils, bean weevils, pantry pests of various kinds, and mill insects; and in the third group are species that can not be controlled by the methods commonly employed for their near relatives. In this last group belong certain other insects that can not be combated satisfactorily by spraying and various wood borers that can not be reached with poisons but can be reached easily with vapors.[1]

[1] It should be noted that the degree of infestation does not affect the dosage required.

FORM IN WHICH CARBON DISULPHID IS SOLD AND WHAT IT COSTS.

In small quantities carbon disulphid is put up in tight tin cans; in large quantities (50 to 1,000 pounds), in steel drums. It may be purchased in small quantities from most druggists at from 25 to 35 cents per pound, but if any considerable quantity is to be used it is better to buy from some wholesale druggist, or, better still, directly from the manufacturers. Manufacturers can supply impure grades, which are commonly used for insecticidal work, at a cost of from 10 to 15 cents per pound. The charge for steel drums is paid by the purchaser, but the drums are returnable at purchase price. Addresses of manufacturers may be obtained from any entomologist or from the director of any experiment station.

PROPERTIES OF CARBON DISULPHID.

LIQUID PROPERTIES.

Liquid carbon disulphid is about one-fourth heavier than water. It evaporates very rapidly upon exposure to the air, the rate of evaporation depending largely upon the area of the exposed surface, the temperature of the air and of the liquid, and the height of the wall of the container above the surface of the liquid. Evaporation may be retarded by mixing the liquid with various substances and is almost wholly prevented by covering the surface with water, which, being lighter, floats easily on top just as kerosene floats upon water. The evaporation takes up heat in proportion to its rapidity so that it may produce frost upon a hot day near the evaporation surface. If the liquid is poured upon the hand or anywhere upon the skin a burning sensation will be felt. This is due not to a burning but to a cooling process, as may be perceived readily by touching the spot with the other hand. No injurious effects result from getting it upon the skin, although it takes out the moisture and oil, leaving the skin dry and whitish. If confined on the skin, as under a ring, it causes sharp, burning pain, and this doubtless is similar to the sensation felt by animals when the liquid is poured into the hair, which serves to retard evaporation.

The chemically pure liquid has a sharp taste and a rather sweetish, not unpleasant, odor which is very similar to that of ether or chloroform. The *pure* chemical is completely volatile and will not injure or stain the finest fabrics. It does not affect the edibility of foodstuffs upon which it may be poured, and all trace of the odor disappears quickly upon full and free exposure to the air. The ordinary commercial article, however, has a decidedly yellowish color, due to the excess of sulphur, and a decidedly unpleasant odor, due to the hydrogen sulphid contained in it. *The commercial article, there-*

fore, should not be poured directly upon goods that would show stains or upon food materials, although the vapor from it will not do them harm.

Liquid carbon disulphid is not at all explosive, and there need be no fear in handling it if the cans are perfectly tight. It boils at 115° F., which is about the highest temperature of water in which the hand can be held. One volume of the liquid is said to produce about 375 volumes of the vapor. The liquid weighs a little over $10\frac{1}{2}$ pounds per gallon at ordinary temperatures.

VAPOR PROPERTIES.

The vapor of carbon disulphid is two and sixty-three one-hundredths times as heavy as air, and therefore can be poured from one glass to another, almost like water. The vapor easily can be seen flowing down over the edge of an open vessel containing the liquid. It diffuses rapidly through the air, as can be perceived from the spread of the odor, but as it tends always to work downward rather than upward, the vapor is more dense and has greater killing power at the lower levels. This point has an important bearing upon the application of the material. The vapor appears to have greater penetrative power than does that of any other volatile liquid that has been tested in insecticidal work. This power is far greater than that of hydrocyanic-acid gas, which is another fumigant frequently used. It is possible, therefore, to use carbon disulphid with good results for the treatment of materials which would not be penetrated by other fumigants under natural atmospheric conditions. The expansive tendency is so great that the vapor may exert a pressure of several pounds to the square inch in the container if the temperature of the liquid is increased. The vapor is highly inflammable and explosive when mixed with air in certain proportions.

EFFECTS UPON HUMAN BEINGS OF INHALATION OF VAPOR.

The gas is rated as highly poisonous, producing giddiness, vomiting, congestion, coma, and finally death. These are, of course, its extreme effects. In its ordinary use on a large scale in the fumigation of mills, warehouses, etc., where the worker may be exposed to inhalation of the fumes for some time, only those effects which precede giddiness are likely to be felt. The first appreciable effect is the perception of a very disagreeable odor, but this odor gradually ceases to be noticed, showing that the sense of smell has been deadened. Workmen may even question the fact that they are handling the same material as at the start. The other senses seem to become benumbed simultaneously, so that the operator does not realize that anything is the matter with him. The heart beat becomes more rapid as the oxygen in the lungs diminishes. The power of thought is very much weakened, and the work is continued in a mechanical way. Hearing and sight are both weakened. But before this weakening process has gone far enough to be really dangerous or injurious the operator probably will feel more or less dizziness. There is no pain or disagreeable sensation, no desire to get away from the vapor, and no sense of suffocation. But when a person has reached this condition it is high time to get into the fresh air.

Owing to the effect of the vapor upon heart action, persons having any trouble or weakness about the heart are cautioned against taking any extended part in the application of disulphid.

It should be understood clearly by those who use it that the action of the vapor is somewhat poisoning as well as suffocating. Should the operator persist in remaining in the room after the dizziness comes on he would be in danger of falling, and, if not discovered, he would soon suffocate. Even if he should get out safely the ill effects would be more marked, and a severe headache, at least, might ensue. If upon the approach of dizziness the operator goes at once to a window, or, better still, out of doors, an abundance of fresh air will remove the ill effects in a few minutes.

The inhalation of the fumes can be retarded somewhat by tying a wet handkerchief tightly over the face. This, however, merely diminishes the amount of air taken into the lungs without affecting the proportion of vapor contained therein. When obliged to enter a room in which there is any considerable amount of the vapor the writer makes use of the following device, which is perfectly effective for a short period. A large paper bag (20 quarts or more) is tied tightly around a short piece of tubing of glass, rubber, or metal inserted into its mouth. When inflated the bag contains sufficient air to enable one to respire into it for several minutes without any discomfort. Being light, it is carried easily by the tube in the mouth so that the hands are left free for any work desired.

PRECAUTIONS TO BE OBSERVED IN HANDLING AND STORING.

The dangers involved in fumigating rooms with carbon disulphid have been discussed rather fully, not because they are very great but in order to lessen the fear that is likely to be great with a material known to involve dangers not fully understood. Danger may be avoided by an intelligent understanding of the precise nature and effects of the chemical. The danger with carbon disulphid is practically of the same nature as that with gasoline, which has come into common use in recent years in many thousands of homes and with hundreds of thousands of automobiles. In reality the danger is less, since every effort is made to keep carbon disulphid from the presence of fire, while gasoline is used principally in connection with fire. The only peculiar thing about carbon disulphid is that the vapor ignites at a lower temperature than does that of gasoline. It may ignite from any form of fire, or even without the presence of flame but with a temperature of above 297° F. *There must therefore be no smoking or carrying around of lights where carbon disulphid vapor is strong, and it is hardly safe to have steam pipes very hot, or to turn on or off an electric light or fan. Even the heavy striking of a nail with a hammer might cause an explosion if the necessary density of vapor were present.* Carbon disulphid should not be applied to corn in the bin or to other grain when the mass is known to be in process of heating spontaneously. The disulphid should be stored in a cool, dry outhouse away from fire and where the containers will not rust out and allow the liquid to escape or evaporate. As a further precaution, all containers should be labeled in red, "DANGER—FIRE."

CONFINEMENT OF THE GAS IN FUMIGATION.

Carbon disulphid is applicable only where the vapor can be confined quite closely. The period during which it is necessary to keep the vapor confined varies with the resistant power of the insect species, but in nearly all cases must be for more than 30 minutes, even when a heavy dosage is being used. It is possible for the gas to be confined sufficiently by the soil, the burrow, a tight room or bin, etc., or even by the large volume of a material through which it can only diffuse slowly.

GAS-TIGHT MATERIALS.

Many writers have referred to tightly closed rooms which are plastered or carefully ceiled as being "gas-tight." As a matter of fact, no such room can be made anywhere near gas-tight. Ordinary living rooms, even in well-built houses, are so very far from gas-tight that a large excess of the fumigant is necessary to get anything like satisfactory results in them. It is not strange, therefore, that a wide divergence appears between the results of experiments made by a scientist in some laboratory in glass receptacles which are truly gas-tight and the results of fumigation work under ordinary building conditions, both in the strength of gas required to kill all insects and in the time in which this can be accomplished.

A somewhat extensive testing of materials has shown that ordinary 10-ounce duck, untreated, will transmit practically 85 per cent as much air under a slight pressure as though there were no such obstacle in the way. All felt materials are extremely porous and are unsatisfactory for use in packing around doors, etc., as they are often used. Heavy, hard-rolled wrapping paper, or 2-ply roofing paper of certain brands, is actually gas-tight and may be used as a lining material between layers of boarding in the construction of fumigation rooms and for pasting over cracks where necessary to tighten a room. Ordinary matched flooring or ceiling alone is very far from being tight.

MAKING A FUMIGATION ROOM OR BIN.

One of the simplest satisfactory containers for fumigation on a small scale is a water-tight barrel. This may be used for the treatment of peas, beans, etc., or for other materials that may be contained therein. The top of the barrel is best closed by spreading heavy wrapping paper, double thickness, over and around the top and tying it tightly.

In making a special room or bin for fumigation work it is best to put on one layer of boards of uniform thickness, flooring or ceiling, and then to cover this with a layer of heavy building paper, tarred paper, or similar material, which is folded or bent to fit into the corners and then is laid so as to overlap 3 or 4 inches and the edges securely pasted or cemented together so as to make it practically one solid piece of gas-tight covering. A final layer of boarding running in an opposite direction to the first is applied to protect the paper from being broken as it is used. Windows should be small and arranged for convenient opening from the outside for ventilation, and door bearings should be against paper surfaces instead of cloth or felt. In such a room or bin fumigation may be practiced with the maximum of efficiency and economy. The application of an ineffective amount of the fumigant is practically a waste of all the material used and often also a waste of the products ineffectively treated.

DIFFUSION OF THE VAPOR.

The vapor diffuses rapidly in the open air, as is evident from the spread of the odor. As has been stated, it must be confined closely in order that a sufficient proportion of it may be maintained in the atmosphere to kill insects, which require far less air, even in proportion to their size, than do higher forms of animals. The vapor naturally tends to spread outward and downward, since it is heavier than air. Consequently when carbon disulphid is applied to a bin of grain or similar material it has been found that the killing proceeds outward and downward from the point of application of the liquid and forms what may be called a "cone of killing." The apex of the cone is close to the point of application, and the base is against the floor or ground below.

EFFECT OF TEMPERATURE IN FUMIGATION.

An extremely important factor that has been ignored until recently in fumigation work is temperature. The effect of temperature may be judged from the fact that a warm atmosphere will require far more of the carbon disulphid vapor to saturate it than will a cool atmosphere. To saturate 1,000 cubic feet of air at 50° F. requires 53.5 pounds of liquid carbon disulphid; at 59°, 64.6 pounds; at 68°, 77.6 pounds; at 77°, 92.4 pounds; and at 86°, 109.3 pounds. Thus at 86° F., which is a temperature not uncommon, the air will hold more than twice as much disulphid vapor as it will at 50°. Not only is this true, but insects show great differences in vital activities at these varying temperatures. The higher the temperatures, up to a certain point, the greater their activity; and the more active the insects are, the more susceptible to the effects of the gas. In practical work it has been found that it is not advisable to try fumigation with carbon disulphid when the temperature is below 60° F., while the most effective and economical work can be done at the higher air temperatures.

AIDING RAPID VAPORIZATION.

In several ways vaporization may be hastened beyond the rate at which it will occur naturally from the surface of the liquid as it is freely exposed to the air. One common method for use in the treatment of rooms and bins on a small scale is to saturate some absorbent material with the desired amount of liquid and hang it near the top of the room or bin so that the vapor may flow away freely downward and produce quickly the maximum density of vapor. Another method sometimes used in large warehouses is to apply the liquid through a spray pump. The operator using this method must be careful not to stay too long in the gas thus rapidly increasing in density. Where the liquid falls upon wood it is taken up quickly by the wood and is then given off again, but slowly. Spray applications sometimes can be made through holes bored in the ceilings or through the floor of the room above that to be treated, and the spray thus distributed at various points in the room below with no inconvenience to the operator. The holes can be stopped securely except when in use. Still another method, which is a modification of the spray method, is to force the liquid under pressure, mixed with a large amount of air, into the material to be treated so that the gas will have to diffuse throughout the material before it can escape and lose its killing power. The more quickly the full killing strength of gas can be attained, the more economical and effective the treatment is likely to be. This method is used especially with cotton seed for boll-weevil destruction.

HOW CARBON DISULPHID KILLS.

The way in which carbon disulphid kills has been studied at the Michigan experiment station,[1] where the conclusions have been reached that carbon-disulphid vapor very probably acts upon the fatty tissues in the insect body, dissolving them to some extent; that it tends to coagulate the proteins; and that it prevents the assimilation of oxygen and the carrying on of other processes which are of vital importance to insect life. A certain amount of respiration goes on at all times so long as an insect is alive, but it is evident that respiration will be far less in the egg stage or during the dormant periods in an insect's life than it is in the adult stage and during the periods of its greatest activity. The strength of vapor and the time required to kill, therefore, will vary greatly and accordingly. Similarly, slow-moving insects usually are harder to kill than the quick-moving forms.

TREATMENT FOR INSECTS INFESTING STORED GRAINS, PEAS, ETC.

The most important use for carbon disulphid as an insecticide in the United States is in the fumigation of stored grains, cowpeas, beans, and peas to kill the insects infesting them. Many species of insects are concerned in this inquiry, but all are susceptible to the same treatment. The most important species attacking corn is the so-called black weevil, or rice weevil,[2] which causes a loss amounting to several million dollars annually in each of the South Atlantic and Gulf States. Probably half of this loss could be prevented by certain inexpensive changes in the methods followed in the planting and handling of the corn crop, but for the other half no method of prevention yet tested can equal fumigation with carbon disulphid.

Investigation by the Alabama Experiment Station has shown that the amount of liquid disulphid required for killing grain insects under ordinary conditions of storage is much greater than has been recommended usually, and ranges up to about 20 pounds per 1,000 cubic feet in ordinary rooms where the walls and floor have not been made especially tight, as recommended on pages 12–13.

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[1] Shafer, George D. How contact insecticides kill. *In* Mich. Agr. Col. Exp. Sta. Tech. Bul. 21, p. 18, 1915.

[2] *Calandra oryza* L.

In large masses of corn containing more than 1,000 bushels, where the corn still has the husk on,[1] it is possible to kill enough insects in the interior of the mass to pay for the fumigation, even if the mass is entirely open to the air above and around it. The husks in so large a mass serve to retain the gas long enough to kill weevils, etc., but it would be better in this case to increase the amount of disulphid to 25 or 30 pounds, dividing it into two equal lots and applying one lot at first and then the other after an interval of an hour. The liquid may be poured directly on the grain, as it will not injure it for feeding purposes or in germination. It is hardly possible thus to treat husked, or even shelled, corn without having a tight room or bin in which to do the work.

In fumigating corn in the crib or storage room it is best to level off the corn and then, if the husk is on, to throw out enough ears to leave five shallow holes in quincunx arrangement (i. e., one at each corner of a square and one in the center, thus: ⁙). If the surface area of the stored corn is oblong it may be divided approximately into squares and five holes, arranged as indicated, made in each square. A proportional part of the entire dosage is then poured into each hole and the ears quickly replaced. The room should be closed as tightly as possible, and it may be left closed indefinitely. The best results are obtained by doing this work when the temperature is above 75° F. Fumigation should begin at about 10 or 11 o'clock in the morning, so that the warmer temperature of midday may increase the effectiveness of the gas.

Cowpeas and other leguminous seeds can be stored and fumigated conveniently in water-tight barrels, which are filled with the seed to within a few inches of the top. The dosage needed, about ½ cupful per barrel, may be poured directly upon the peas or into absorbent material packed on top of them. The barrel then should be covered with a double thickness of heavy wrapping paper tied closely and

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[1] Husk corn in the field.—In the Southern States it has been long the prevailing custom to gather the corn by breaking the ear from the stalk and to store it with the husk on. For several reasons insect injury during storage is generally far greater in the South than it is in the North. Storing corn with the husk on has been supposed to protect it against insect attack in some measure. Recent investigations have shown that this is a mistake in practice. The insect attack begins in the field as soon as the kernels begin to harden and the husk to shrink away from the ear. *Storing with the husk on insures carrying practically every insect from the field to the crib. It practically doubles the volume of storage room required per bushel of corn and also increases greatly the amount of carbon disulphid needed to treat the corn in the crib. Husking the corn in the field, on the other hand, will leave at least three-fourths of the adult insects in the field and thus help greatly in reducing subsequent injury during storage, besides making crib treatment more effective and economical.*

There is no need for an open crib in which to store the thoroughly well-matured corn of the South. Storage rooms may be made tight enough for fumigation and the dosage required for bare ears will be only about 10 pounds per 1,000 cubic feet, or one-half the amount needed with the husk on. Store as soon as the corn is thoroughly matured and fumigate promptly for best results. If insect attack develops in the crib, treat again, using a heavier dosage, or doing the work during warmer weather.

tightly around the top. After a few days the peas should be examined, and if insects are still active they should be treated again, a stronger dosage being given or the work done on a warmer day. The barrels may be kept covered with the paper to prevent reinfestation. The sooner peas are thrashed out and thus treated the better. Treatment should kill immature weevils as well as adults. Other seeds intended for planting can be treated and protected in a similar manner.

TREATMENT OF BUILDINGS.

Agricultural products frequently are brought together in storehouses, mills, etc., in immense quantities, and when allowed to stand for months, as is frequently the case, these materials become particularly favorable places for the nourishment and multiplication of a large variety of insects which can be dealt with only by treating the entire building. It is possible that this fumigation treatment might be objected to by fire-insurance companies as a violation of the policy contract, but there is no record of fire ever having occurred from such treatment of warehouses or mill buildings.

PRELIMINARY INVESTIGATIONS.

When a fumigation of this kind is to be undertaken, a preliminary investigation should be made to determine the nature of the principal pest (or pests), its habits, manner of injury and of breeding, and as much of its life history as may be needed to determine whether one time will be more favorable than another for the treatment. The building or room should be examined thoroughly to determine how it can be made as nearly tight as possible, and its floor area and cubical contents computed. All possible objections to treatment and all dangers involved should then be considered. As a general rule, the advice of a competent entomologist may be obtained free through the State experiment station, and in many cases the entomologist can be secured to take personal charge of the preparation of the building and the application of the treatment.

PREPARATION OF THE BUILDING.

The building should be made as nearly gas tight as is possible and the places into which the insects might crawl for shelter should be eliminated so far as practicable. The pasting of heavy wrapping paper over cracks around the floor edges and around windows, doors, etc., is one of the cheapest and best ways of closing these spaces. Insects sheltered in such cracks may be killed by local treatment. The building should be swept out thoroughly, and a coat of whitewash may be needed sometimes before the treatment is applied. As much as possible of the infested materials should then be exposed to the strongest action of the vapor. With this in view, materials should be removed from shelves and spread out on the floor. If there are serious objections to allowing the liquid to touch the materials to be treated, it will be necessary to provide a large number of shallow tin pans or plates. The larger these are the better. They should be placed as high in the room as can be done without delaying the application unduly, and care should be taken to see that they are level, although ordinarily no harm will be done if some of the liquid is spilled. No time can be lost in making such adjustments after the application is begun. To reach places which are not accessible by the pan method, it may be possible to use cotton waste or other absorbent material, saturating it with the disulphid and throwing it or hanging it where needed. If the liquid has been purchased in bulk it may be necessary to have several convenient smaller receptacles into which it may be poured so that it can be handled conveniently and rapidly.

MAKING THE EXPOSURE.

As many men should assist in making the exposure as can work to advantage, for the work must be done rapidly. Before the cans or drums are opened every man should receive full instructions as to his division of the work, and cautioned as to the dangers from fire, dizziness, etc. If more than one floor is to be treated, the men should begin at the bottom and work upward on account of the rapid settling of the gas. Every door and window should be closed tightly except that left for escape of the workers. All should begin at the same time, pouring the predetermined amount into each receptacle, and then get out into the open air as quickly as possible. The exit door should then be closed, with paper pasted around it to make it tight, and it should be left closed for 12 hours or longer. The best plan usually is to make the treatment on Saturday afternoon before dark, or on Sunday forenoon, and allow the building to remain locked until early Monday morning. Owners of adjoining premises should be advised regarding the nature of the work, and a watchman may be needed in some cases during the period of treatment.

VENTILATION.

As a matter of fact, most, if not all, of the killing will have occurred during the first 6 hours of the exposure and the building may be ventilated after that time, as a minimum, has elapsed, although it is better to wait 12 hours or longer. In cases of long exposures the vapors will have diffused so fully by the end of 24 hours that there will be no danger to anyone entering the building to open it for ventilation. If, however, it is found that the gas is still very strong, the respiration bag, as described on page 6, should be used. The odor disappears rapidly where the air is moving at all. Traces of it may linger in close or damp corners for some time, but there is no danger from fire or to health from slight amounts of vapor.

FUMIGATION OF SACKED COTTON SEED.

On account of its fuzzy nature and the immense number of small air spaces formed in tightly packed masses of cotton seed, this material has proved to be a difficult subject for fumigation. Hydrocyanic-acid gas does not penetrate more than a few inches into cotton seed, which carbon-disulphid vapor can penetrate for several feet downward from the point of application of the liquid, but the penetration by its own force is slow and the loss of time is unnecessary. A method of forcing specified quantities of the liquid and its vapor into the interior of the mass of cotton seed, or into sacks of seed, has been devised and described.[1] By this method a squad of four men can treat 600 or more sacks of seed a day. A charge of 1 ounce of disulphid is used for each sack of seed containing about 3 bushels, and the liquid and its vapor are driven into and diffused through the seed by pressure of air obtained from a small air pump. The cost for liquid used amounts to less than one-third of a cent per bushel, and the expense for the treatment, including labor, will be about one-half cent per bushel. This method of application can be used with many other subjects to good advantage. The liquid and vapor are released in the interior of the mass to be treated, thus confining all the vapor and forcing it to diffuse throughout the material before it can escape and lose its killing power.

DESTRUCTION OF ANTS.

Carbon disulphid is the best remedy known for the destruction of colonies of ants, which frequently become great nuisances to householders, farmers, and gardeners. With a little careful observation most of these ants, except possibly the little red house ant, can be traced to their outdoor homes. It helps little to destroy even a large number of the workers, as the supply will be renewed quickly through the rapid breeding of the colony. The only really effective way of stopping the annoyance or injury is to destroy the queens which lay the eggs and rarely leave the nests.

In work with the Argentine ant in Louisiana[2] it was found that the colonies could be localized during the winter season or in very wet

[1] Hinds, W. E. Fumigation method for sacked cotton seed. *In* Jour. Econ. Ent., v. 8, no. 4, p. 400–402, pl. 21. 1915.

Hunter, W. D. The boll-weevil problem, with special reference to means of reducing damage. U. S. Dept. Agr. Farmers' Bul. 512, p. 37–39, fig. 9. 1912.

[2] Newell, Wilmon. Measures suggested against the Argentine ant as a household pest. *In* Jour. Econ. Ent., v. 2, no. 5, p. 324–332. 1909.

situations by furnishing warm places for the nesting of the ants. For the winter, trap boxes 2 by 2 by 3 feet in size were filled with leaves, cotton seed and straw or other porous material. These were placed in the open about the 1st of October, so that the contents might be wet by the rains and then become warm through the process of decay. This material proved so attractive to the ants that practically all colonies within a radius of 30 or 40 yards would take up their abode in it as cool weather came on. In a single trap of this kind it was estimated that more than 1,000 fertile queens were present. In midwinter the cracks in the box were closed tightly, the top covered with a waterproof canvas, and carbon disulphid applied, so that all ants were destroyed at once. This appears to be one of the most economical and effective methods for controlling the Argentine ant.

In the destruction of colonies of the agricultural ants which are very common in the southwestern States carbon disulphid treatment has given most satisfactory results.[1] The liquid is evaporated under an airtight, galvanized-iron tub, which is inverted over the entrances to the colony. The fumigation is begun when the gateways to the nest are open, thus permitting the vapor to flow into the tunnels and penetrate to the lowest chambers in the nest. If other openings occur that can not be covered with the tub at one time, they should all be closed by piling dirt around the tub. One to three ounces of liquid should be used, depending upon the apparent size of the nest, and the tub allowed to stand for five or six hours. By this time all ants will have been killed, and the tubs may be moved to other colonies.

Where ants infest the surface soil generally throughout a considerable area, holes not more than 18 inches apart and several inches deep may be made with a stick or iron bar, an ounce of disulphid poured into each, and the holes closed immediately. After the whole area has been treated the ground should be wet thoroughly or covered with waterproofed canvas, or paper, or wet blankets, to aid in confining the gas.

USE OF CARBON DISULPHID AGAINST WHITE GRUBS AND MOLE CRICKETS.

White grubs, which are the young of the so-called May beetles or June beetles, occur throughout the United States and frequently are so abundant as to demand treatment. Their period of development is long, extending over two or three years, and during this period they are feeding upon the roots of plants. Mole crickets are most abundant in the Southern States and in the islands in the Gulf of Mexico, and they produce a full generation each year. Both of these

[1] Headlee, T. J., and Dean, Geo. A. The mound-building prairie ant. Kans. Agr. Col. Exp. Sta. Bul. 154, p. 178–180. 1908.

common pests in gardens and lawns may be destroyed by the method recommended for use against ants infesting the soil. For best results the soil should be fairly permeable and at least 8 inches in depth.

TREATMENT FOR APHIDS LIVING UNDERGROUND.

The first extensive use of carbon disulphid as an insecticide was against the grape Phylloxera in France. The Phylloxera is a species of aphis which lives upon the roots of the vine. It is native to America but was introduced by accident into France about 1859, where for a time it threatened to destroy the grape-growing industry. By 1863 more than 200,000 acres of vines were being treated annually with carbon disulphid for this pest. The following paragraphs give a brief summary of the principal conclusions reached by French workers in their fight against the Phylloxera. They are included here because they have a general application to all fumigation for underground insects.

DIFFUSION OF THE VAPOR IN THE SOIL.

The liquid evaporates in the soil as it does in the air, only much more slowly. The vapor diffuses through the air spaces of the soil, producing an atmosphere that may be fatal to all insects reached by it. The rate of evaporation, extent of diffusion, and persistence of the vapor in the soil vary widely in soils of varying character and condition. It becomes necessary, therefore, to vary the rules for application according to the influence of these factors to secure the destruction of all insects without injury to the plants.

EFFECT OF SOIL MOISTURE.

Carbon disulphid evaporates most rapidly in a warm, dry, sandy soil, and the persistence of the vapor is shortest in such soil. In fact, in such soil the diffusion is so rapid that most insects will survive an ordinary treatment, and if the dose is increased greatly to kill the insects there is grave danger of killing the plants also. Treatment can not be applied successfully in such soil unless the surface soil can be wet or covered after the treatment. On the other hand, diffusion is slowest in very heavy, wet, clay soils, and when the soil is saturated with water the evaporation is almost entirely prevented. Moisture lowers the temperature and decreases the permeability of the soil; it also prevents evaporation and retards diffusion. Between these two extremes there is a medium character and condition of the soil which is most favorable for the treatment.

EFFECT OF CHARACTER OF THE SOIL.

Sandy soils permit an even but too rapid diffusion and loss of vapor. Rocky soils are not of even texture, and naturally the vapor follows the line of least resistance. Heavy clay soils, when very dry, are usually much broken by cracks and fissures which may run from the surface to a considerable depth and permit the gas to escape without permeating the soil to any considerable extent. When such soil is moderately moistened it is even in texture and favorable to treatment.

DEPTH OF SOIL.

The depth of the soil is an important factor in determining how much disulphid should be used for a given area. If surface soil is very shallow and the subsoil very dense and impervious, it is evident that much less liquid will be required to produce a killing atmosphere than will be needed in soil of much greater depth. The amount of liquid used should be proportional to the permeable depth of the soil. In heavy, compact soils increase the number of injections and diminish the dose in each; in light, deep, permeable soils decrease the number of holes and increase the dose in each.

AMOUNTS TO USE.

Grapevines growing in medium fine, moderately moist soils were uninjured by doses of from 1 to 1½ ounces in each of three holes made at about 16 inches from the base of the vine and at a depth of about 20 inches, while 2½ ounces to a hole proved fatal to them.

REPEATED TREATMENTS.

Best results are obtained by dividing the amount of liquid to be applied and giving two applications of the half dose, separating the applications by from 6 to 10 days. The holes made for the second treatment are then placed intermediately between those used for the first. The depth of holes may range from 12 to 16 inches. Spring is the most favorable season for treatments.

TREATMENT FOR ROOT-MAGGOTS.

Carbon disulphid has been used with varying degrees of success for the cabbage root-maggot since 1880. Its efficacy varies considerably with the nature of the soil, and many of the failures reported have been due very largely to improper or too tardy application. If the liquid comes into direct contact with the roots of the young plants, it is sure to prove fatal, but a considerable proportion of the vapor will do no harm. If treatment is delayed until after the plants have wilted, it is very likely that they will not recover, even though the enemy may be killed, but the death of such plants in such cases can not be attributed fairly to the disulphid treatment. Many growers who have tested it thoroughly claim that it will work in either clay or sandy soil, and that it destroys both maggots and pupæ. In applying the disulphid for root-maggots the dose is distributed in one or two holes made not nearer than about 4 inches from the base of the plant and running down to a point a little below the roots. The holes must be closed tightly with earth and compacted by pressure with the foot. The dose varies from 1 teaspoonful for each small plant to a tablespoonful for large plants.[1] One injection should be sufficient if made in time, but if delayed too long nothing can save the plants.

TREATMENT FOR APHIDS ON LOW-GROWING PLANTS.

Aphids frequently become extremely abundant upon melon, citron, and other cucurbit vines and upon young cabbage plants, etc. Here they are very hard to control by spraying with contact insecticides because of the curling of the leaves. Carbon disulphid has been used successfully for the control of melon aphids by evaporating the liquid under a tub which covers the vines. Another form of covering used for the plants is a box made of a light frame of wood about 24 inches square by 8 inches high, covered with closely woven muslin cloth which is soaked with linseed oil and then dried to make it gas-tight. The cloth is made to project some 6 or 8 inches beyond the frame so as to form a loose flap around the outside upon which dirt can be piled to make the covering fit tightly to the ground. These boxes are light, durable, and convenient to handle.

The dose consists of 1 teaspoonful (1 dram) of liquid to a plant, or for a box containing about 1 cubic foot, and should be increased proportionately with larger boxes. If the receptacle is of irregular shape, but water-tight, the contents may be determined very accurately by filling it with water. It takes very nearly 7½ gallons (30 quarts) of water to fill 1 cubic foot of space.

The liquid may be evaporated from a shallow dish, or arrangement may be made so that the liquid can be poured through a large hole in the top of the box into some absorbent material fastened permanently beneath it, and the hole then closed tightly with a stopper. On account of the small space that is being treated, special care should be taken to measure the amount of liquid accurately. The covers should remain in place for one hour and then be moved to fresh plants. With from 50 to 100 boxes, a field may be treated with comparative rapidity, and the vapor will reach the aphids much more thoroughly than if applied in any other way. Plants will be more resistant to the vapor at night, when the breathing pores (stomata) are closed.

[1] Four teaspoonfuls are approximately 1 tablespoonful, and 2 tablespoonfuls are approximately 1 fluid ounce.

DESTROYING WOOD-BORERS.

Much has been written concerning the use of carbon disulphid to destroy borers in wood. It is evident that only the larger borers which work in the trunks and larger branches of valuable shade and fruit trees will be good subjects for this work. Usually there are few of these large borers in a trunk, and the outlets to their burrows are marked by the "saw-dust" and castings which they throw out from them. In attempting this treatment, first close all burrows with a clay plug and after a day or two re-examine them to see what burrows are really occupied. Clean-cut, empty holes in the trunk are likely to be only the exit holes from which insects have emerged, so it would be a waste of time and materials to treat such cavities.

METHOD OF TREATMENT.

Having cleaned out the mouth of the hole as well and deeply as possible, roll a small wad of cotton on a toothpick, wet it with disulphid, push it into the cavity as far as possible, and immediately close the hole tightly with putty or, better, with grafting wax. Only a drop or two of liquid is likely to be needed and it should not be applied so as to run down into the burrow as a liquid. The vapor should penetrate to the farthest part of the cavity and destroy any stage of the borer that may be present.

A similar method has been used very successfully by the writer in destroying borers that were working in a piano. No treated burrow was ever opened.

TREATMENT FOR CLOTHES MOTHS AND FOR OTHER HOUSEHOLD INSECTS.

The various insects which commonly infest woolens, felts, furs, etc., often can be conveniently and surely destroyed by carbon disulphid, which will destroy all stages of the pests that may be present. In keeping woolens, felts, and furs, therefore, it is good practice to place them in a whole cotton bag (pillow case), tying it up tightly, and then store in a tight paper-lined trunk, a large packing box, or some such receptacle. (A water-tight barrel will do well.) When all are stored apply the disulphid, putting one-half cupful of the liquid into a shallow dish to evaporate or pouring it directly upon the materials if staining will not injure them. Newspapers or wrapping paper then should be spread over the top and the receptacle closed tightly. If the box is really tight there will be no further trouble, but to be on the safe side it is well to repeat the treatment once or twice during the summer. The odor disappears quickly when the articles are hung out in the open air again.

It is a good plan to provide for this treatment, which is needed in every home, by having an especially large, gas-tight and insect-tight packing chest with a very closely fitting cover. A hole should be bored through the cover and a small sponge, bunch of cotton waste, or similar absorbent material fastened below the opening on the inside. The chest may then be kept tightly closed and the carbon disulphid applied by pouring it through the opening, which thereupon is closed with a cork. The small cost of such an arrangement will soon be balanced by the convenience and security of the protection afforded. Carpets, rugs, blankets, woolen clothing, furs, etc., can be rid surely of all insect pests by inclosure for a few days in such a box. The dose used should be at the rate of at least 10 pounds to 1,000 cubic feet.

Among the numerous insects found in houses there are few that may not be reached successfully with carbon disulphid applied as directed for the fumigation of buildings. (See pp. 12–14.) Cockroaches, croton bugs, bedbugs, fleas, carpet beetles, etc., all can be destroyed by proper use of this liquid. The holds of large ships frequently are cleared of such pests, and also of rodents, in this manner.

DESTROYING MUSEUM PESTS.

Carbon disulphid is used very generally for the destruction of a number of insect pests which ruin museum specimens. Such specimens usually are inclosed in fairly tight showcases, trays, or boxes, and these can be treated rapidly and successfully simply by inserting the necessary amount of liquid and then closing doors or covers normally. In this way many museums are treated regularly as a measure of precaution, even though no pest is known to be present. Sometimes specimen trays or materials are placed in especially constructed, tight rooms or chests within which one general treatment reaches all of the contents. With this method care must be taken to see that boxes and trays are opened so that the vapor can diffuse through all of them.

SPECIES FACTOR IN INSECT RESISTANCE TO CARBON DISULPHID.

Great variation has been found in the resistance of different species of insects to carbon disulphid fumigation. This may be spoken of as the species factor and should always be considered in such work. Just as in the case of ordinary insect-killing bottles in which sodium cyanid is now used, the bumblebee probably is the easiest insect to kill with carbon disulphid. In a saturated atmosphere of disulphid at about 90° F. a bumblebee will die in a few seconds, while under the same conditions the cowpea weevil[1] will live for about 35 minutes, the rice weevil[2] for about 60 minutes, and the saw-toothed grain beetle[3] for about 120 minutes.

EFFECT OF CARBON-DISULPHID FUMIGATION UPON THE GERMINATION OF SEEDS.

It would appear from numerous tests that there is practically no danger of injuring germination in treating seeds that are well matured and dried out before treatment is given. *It would not be wise to treat moist seeds, or planting seed of any kind, during periods of very humid atmosphere,* as the seeds might take up enough moisture to make them liable to injury from the vapor.

SUBSTITUTES FOR CARBON DISULPHID IN FUMIGATION WORK.

A number of other volatile materials have been tested more or less carefully in the search for a fumigant that would be as effective as carbon disulphid and safer to handle on account of having non-explosive qualities. Among this number carbon tetrachlorid is probably of largest value, but even with this material it is necessary to use several times as much as is required of carbon disulphid, and the fumigation to be effective is several times as expensive. It does not appear probable that any of these substitutes is likely to come into general use.

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[1] *Pachymerus chinensis* L. [2] *Calandra oryza* L. [3] *Silvanus surinamensis* L.

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MITES AND LICE ON POULTRY

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"Pinch method" of applying sodium fluorid to a fowl infested with lice

FARMERS' BULLETIN 801
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Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

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Show this bulletin to a neighbor. Additional copies may be obtained free from the Division of Publications, United States Department of Agriculture

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ASIDE from the chicken tick and the sticktight flea, the most important external parasites of fowls are the common red mite, the scaly-leg mite, and various lice.

The common mite sucks blood from the fowls and breeds in the cracks of the roosts and buildings. It may be destroyed by two or three applications of crude petroleum or one of the commercial carbolineums to the roosts and buildings.

Scaly leg is caused by a small mite which may be destroyed by dipping the legs in crude petroleum.

In addition to a description of mites and lice this bulletin tells of a new but cheap and effective insecticide for use in destroying poultry lice. It is sodium fluorid, a white powder, which can be obtained through druggists. A single application, which costs about half a cent, will destroy all of the lice on a bird. Hundreds of fowls have been treated in the experiments conducted, but no injury whatever to them has occurred. Full instructions regarding methods of application are given in the bulletin.

Care in its use to avoid burning of the hands is advised.

MITES AND LICE ON POULTRY.

CONTENTS.

External parasites are one of the most important factors operating to retard the development of the poultry industry, but it is difficult to determine which of the parasites are of greatest importance. Both lice and mites are found in practically every locality where poultry are raised. Where present in any considerable numbers both lice and mites reduce egg production and hinder the growth and reduce the quality of flesh of all classes of poultry.

MITES.

THE COMMON CHICKEN MITE.[1]

Poultry raisers are all too familiar with the common red or gray mite which infests poultry houses. In general those who are making a specialty of poultry raising have comparatively little trouble with mites, or at least they keep them reduced to a point where they are of little importance. On the other hand, farmers and others who raise poultry as an incident to other operations frequently find their chicken houses overrun by mites. The attack of this blood-sucking mite is of an insidious nature which does not readily draw attention to its presence, and often the poultryman is not aware of an infestation until he is attracted to it by the irritation produced by mites on his own body through coming in contact with the infested coops. The presence of the pest may be determined readily by the detection of small areas on the boards specked with black and white as though dusted with salt and pepper. This is the excrement of the mites, which are hidden in adjacent cracks or rough places. More careful examination will reveal masses of mites in hiding, together with their eggs and the silvery skins cast by the young. In moderately infested

[1] *Dermanyssus gallinae* De Geer.

poultry houses the injury to the fowls is not at once apparent, but the constant blood loss and irritation are shown by decreased egg production and the poor condition of the flesh of fowls. In heavily infested coops it is not unusual for the chickens to become droopy and weak, with pale comb and wattles. Sitting hens desert their nests and thus ruin the eggs or, as is often the case, they are found dead on the nest, being killed outright by the attack of thousands of mites. In extreme cases a considerable percentage of the fowls succumb, even though not sitting, and all are so weakened as to be very susceptible to various diseases.

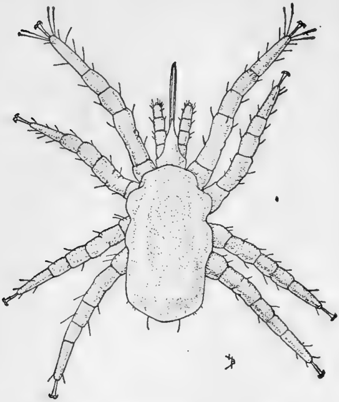

FIG. 1.—First nymphal stage of the chicken mite, unfed. Greatly enlarged. (Original.)

DISTRIBUTION AND ABUNDANCE.

While the species sometimes becomes very numerous in the chicken houses in the northern part of the United States, the shorter breeding season there usually makes it of less importance than in the South where breeding continues throughout the year with little or no interruption. Although many assert that dampness has much to do with the abundance of the chicken mite, experience has shown that the mite occurs in rather greater numbers in the semiarid and arid regions of the Southwest than in the more humid parts of the South.

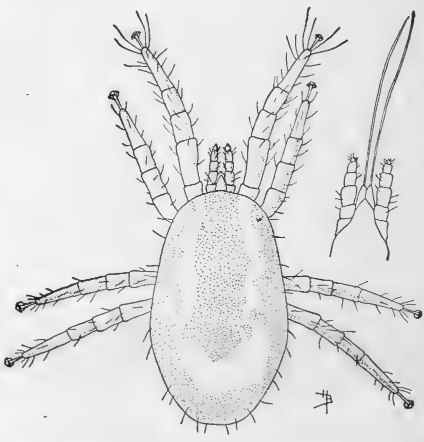

FIG. 2.—Female chicken mite before feeding, greatly enlarged. Mouth parts at right more highly magnified. (Original.)

LIFE HISTORY AND HABITS.

Blood is absolutely essential for the development of this mite in all stages. The mite feeds almost entirely at night, except that it often feeds on hens on nests.

Chickens may carry a few mites (sometimes a hundred or more) in their feathers during the day following a night spent in infested quarters, but most of these leave the host during the following night. In some cases mites may remain on chickens during three days and nights, but nearly all become engorged and leave them by the third night.

Within 12 to 48 hours after receiving a meal of blood the mature female deposits from three to seven pearly white and elliptical eggs laid singly in the cracks in which the adults are hiding. The operation of feeding and depositing is repeated as many as eight times, and from 25 to 35 eggs in all are deposited.

In summer the eggs hatch in about two days, and one to two days later, without feeding, the larvæ shed their skins and become nymphs (see fig. 1). With a very short rest these light-colored nymphs engorge with blood, secrete themselves, and molt their skins the second time 30 to 48 hours after having fed. These mites of the second nymphal stage soon engorge again, shedding their skins one to two days later and becoming adults. The grayish-colored unfed adult is shown in figure 2, and the engorged female, dark red in color and quite plump, in figure 3.

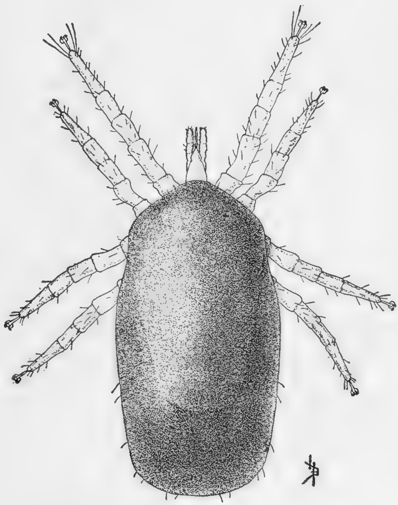

Fig. 3.—Female chicken mite after feeding. Greatly enlarged. (Original.)

Thus the chicken mite reproduces very rapidly, the complete life cycle from egg to adult requiring not more than seven days.

The weather is never too hot for this mite to thrive, and development is most rapid in midsummer. In the Southern States the mites are not entirely dormant during the winter, but feed and develop when the temperature is not low. This is also true in the North in chicken houses that are heated. Where some development takes place throughout the year, and where a complete generation of mites is developed in a week's time, hordes of mites will be present in a poultry house within a comparatively short time if something is not done to destroy them.

LENGTH OF LIFE.

It is probable that in a poultry house once infested at least four months and probably five will be required before all of the mites will starve if the chickens are removed from the house. In tests made by the writers some mites were still alive after a period of 113 days, and since these individuals were collected from an infested house it is not unlikely that they had matured some time previously. The tests indicate that where the mites are supplied with a certain amount of moisture they will live longer than when kept under very dry conditions. This may account, in part at least, for the idea that mites are worse in damp and badly ventilated chicken houses.

HOSTS AND METHODS OF SPREAD.

Chicken mites do not feed to any great extent upon other hosts when chickens are at hand. They are carried about chiefly by the interchange of poultry and in crates and boxes in which fowls are shipped. No doubt clean premises sometimes are infested by mites carried on the clothing of people going from one chicken yard to another.

CONTROL.

Owing to the fact that mites feed during the night and secrete themselves in cracks and crevices during the day, their presence very often is overlooked until a very heavy infestation has developed. In such cases they should be attacked energetically. Although not hard to kill, the greatest obstacle is the difficulty of reaching them in their hiding places. Dust baths will not control them, as at most only the few which remain on the chickens during the daytime will be destroyed.

TREATMENT OF INFESTED CHICKEN HOUSES.

The first step necessary to destroy the mites is to get rid of the hiding places so far as possible. The roosts should be taken down and all unnecessary boards and boxes removed. In heavily infested houses the mites are to be found in all parts of the building, including the roof. Where they are less numerous the infestations usually are confined to the roosts and nests and the walls immediately adjacent. For small coops a hand atomizer will suffice for applying insecticides as sprays, but for larger houses a bucket pump, knapsack sprayer, or barrel pump is desirable. A rather coarse spray should be applied from all angles and thoroughly driven into the cracks. The floor also should be treated, as many mites fall to the floor when the roosts are being removed.

In tests conducted during the last four years several different materials used as sprays have proved effective against mites. Commercial carbolineum which consists essentially of a high-grade anthracene oil has proved very effective. The killing power of this substance, which is derived from coal tar, lasts for several months, and mites which may be inclined to come in from other buildings are repelled for a long time. This material is rather expensive—about $1 a gallon—but since the number of treatments necessary to control an infestation of mites completely is less than when any other known material is used, its application is strongly advised.

Crude petroleum, while not as effective as carbolineum, retains its killing power for several weeks, and in most localities is very cheap. Since it does not dry into the wood so rapidly it is more likely to soil the fowls and clothing. Both of these materials can be sprayed better if reduced with kerosene at the rate of about 1 part of kerosene to 3 parts of the other materials. Both of them often contain foreign particles which should be strained out before the spraying is begun. It has been found that one thorough application of either of these materials will often completely eradicate the mites from an infested chicken house, but ordinarily it is advisable to make a second application a month after the first, and in some cases a third treatment is required. These subsequent applications may be made with a brush, the materials being used pure and only the roosts, their supports, the walls adjoining, and the nests if they are infested, being covered. This method of application is effective for the first treatment also if the houses are not heavily infested. Poultry should be kept out of the treated buildings until the material is well dried into the wood.

It is advisable to spray or paint chicken coops a few days before putting broods of young chicks into them.

In spraying hen houses care should be exercised to prevent the spray from striking chickens around the building. This is especially important with young chicks.

Pure kerosene and kerosene emulsion in double the strength ordinarily applied to plants will destroy all mites hit, but these substances have not body enough to destroy those mites which are in more protected situations, and several applications at 10-day intervals are needed to destroy all the mites.

Arsenical dip, such as is used to destroy cattle ticks, has been found fairly satisfactory for use against chicken mites. Several applications are required to eradicate the mites from poultry houses. In regions where cattle dipping is practised and this solution is readily available, it is perhaps the most convenient and cheapest material to use. Of course due care should be taken to avoid the accidental poisoning of the fowls. The standard coal-tar stock dips, used in solutions slightly stronger than are recommended on the cans, will destroy all mites reached by the spray, and in addition their germ-destroying properties are a desirable feature.

In tests made by the writers lime-sulphur solutions such as are used against scale insects proved much less effective than the insecticides already mentioned. Standard indoor whitewash [1] with 5 per cent of crude carbolic acid or cresol added gives good results, although

[1] Methods of making whitewashes are discussed in Farmers' Bulletin 474 of the Department of Agriculture.

not equal to those obtained by the use of crude oil or the wood preserver mentioned. Dry sulphur or lime will not control this mite.

With any insecticide the results will depend largely on the thoroughness of the application.

ROOSTS AND NESTS.

After the first spraying it is advisable to put in new roosts if the old ones furnish many hiding places for mites. The roosts should never be nailed to the side of the building but arranged so as to be easily removable. A convenient form of roost is shown in figure 4. The supports for the roost poles should consist of two 2 by 4's on edge in a horizontal position. The ends of these rest in notches cut in the ends of four uprights made of 2 by 6's and driven into the ground or nailed to the floor. The roosts should consist of smooth 1 by 3's or 2 by 2's, the ends resting in notches cut in the 2 by 4's. If the notches fit the poles closely, it is unnecessary to nail the latter. The roosts thus are removed easily when the chicken house is to be cleaned, and a coat of one of the mite destroyers mentioned can be applied to the ends of the roosts occasionally. If dropping boards are used they can be made to fit up to the four posts. In larger houses the horizontal 2 by 4's may be fastened to the back wall with hooks or certain types of screen hangers.

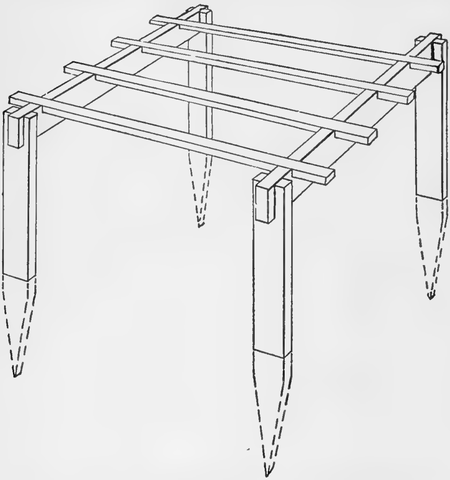

FIG. 4.—Chicken roost, suggesting method of making treatment for mites easy. (Original.)

Another method of constructing the roosts, which is especially applicable to the Southwestern States where the chicken tick occurs, is to suspend a frame from the ceiling on baling wire and place the roosts across this frame. None of the structure should be allowed to come in contact with the walls, and there is then little opportunity for mites to reach the chickens. The underside of the roosts must be watched, however, to see that mites have not been introduced accidentally, as they have been known to breed on such roosts until present in considerable numbers.

If convenient, the nests should be entirely apart from the roosting quarters. They may consist of boxes, which are easily handled, cleaned, or, if infested, destroyed. A series of nests made of boards is not objectionable if placed on a framework free from the walls of the henhouse and easily removable for cleaning. The simple arrangement devised by Prof. Herrick and illustrated in figure 5 may be used. Wooden or iron brackets (*a*) are fastened to the wall and upon these are laid a 12-inch and a 6-inch board, the latter behind (*b*). These form the bottom of the nest and a shelf for the fowls to stand on in entering the nests. The back of the nests is formed by the wall, and the partitions are made by cutting a 12-inch board into pieces 12 inches long (*c*) held upright by a 1 by 3 (*e*) nailed on top even with the back edges and a similar strip (*d*) nailed along the front at the bottom. The partitions and the bottom can be readily lifted off and thoroughly cleaned and the wall behind treated. Usually it is advisable to hinge to the wall a sheet of corrugated iron in such a way as to form a slanting roof over the nests to give seclusion and prevent fowls from roosting on them.

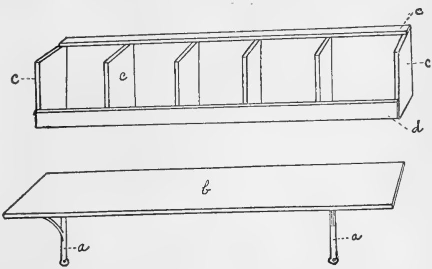

FIG. 5.—Simple nest boxes. (Herrick, with modifications.)

Great care should be taken to keep nests occupied by sitting hens free from mites. It is hard to work effectively against the mites when many hens are brooding; moreover, oil used freely about the house at any time may soil the eggs and prevent successful hatching. Infested quarters, therefore, should be treated thoroughly in the late winter before hens are set, so as to start them in nests which are absolutely clean. Beneath the straw of the nest a layer of lime and sulphur will tend to prevent mite breeding, and the entire nest may be dusted occasionally with pyrethrum. Broken eggs and the straw soiled by them should be removed promptly, as they tend to attract mites.

In case an infestation of mites is discovered in nests where hens are sitting it is advised that the corners and cracks of new nest boxes be painted with carbolineum, after which the hens should be supplied with new nest material and the eggs and hens transferred during the day time. The old nests should be burned or well sprayed.

When poultry are to be transferred to new quarters it is desirable that they be kept three days and nights in a pen so that the mites will leave them before their introduction into the new building. The roosts in the new building and in the quarantine cage should be treated in order that any mites which have left the fowls may be destroyed.

SCALY-LEG MITE, DEPLUMING MITE, AND OTHER MITES.

Two species of itch mites attack fowls, one of which [1] is the cause of scaly leg. While this mite commonly remains on the feet, burrowing

FIG. 6.—Dipping the legs of a hen in crude petroleum to kill the scaly-leg mite.

through the scales and causing their enlargement, it also attacks the comb and the neck. A crust of loose tissue is formed above the burrows, and intense itching results from this mining habit. When

[1] Known scientifically as *Cnemidocoptes mutans* Robin.

scaly leg is left untreated the feet often become badly distorted, and in some cases the fowl can scarcely walk or get up to the perch. Sometimes terminal joints of the toes are lost. As the mites are transferred from one bird to another, scaly-leg fowls should be treated promptly and should not be introduced among clean birds. Carbolineum or crude petroleum used on the roosts doubtless will aid in preventing the spread of the scaly-leg mite from one fowl to another. Applying crude petroleum to the legs with a brush or dipping the legs into this oil (fig. 6) is very effective. One application usually is sufficient, but if the scales are not largely shed off after a lapse of 30 days the treatment may be repeated. Kerosene oil is applied by some farmers in the same way, but is less effective than crude oil. In using either, care should be taken not to get the oil on the upper part of the leg or on the feathers. A less severe but more laborious treatment consists of soaking the feet in warm soapsuds until the scales are loosened and then greasing the feet and legs with sulphur and lard, or lard containing 6 per cent crude carbolic acid.

The other itch mite,[1] commonly called the depluming mite, is a very small creature which burrows into the skin near the base of the feathers. The intense itching sometimes causes the fowls to pull their feathers until they are almost naked. Dipping of all fowls of an infested flock in a tub of water containing about 2 ounces of flowers of sulphur and one-half ounce of laundry soap to each gallon of water will give complete control. The fowls should be completely submerged and the feathers ruffled as described in the dipping process with sodium fluorid. Care should be taken to keep the dip stirred during treatment so as to keep the sulphur in suspension. In case a flock has lice as well as the depluming mite, three-fourths ounce or one heaping tablespoonful of sodium fluorid may be added to each gallon of water in the foregoing mixture.

There are two other species of small soft-bodied mites sometimes found on poultry. One of these [2] bores into the skin. The other,[3] which has been found in several places in this country, occurs in the air passages, lungs, liver, and other internal organs of chickens and turkeys. Serious injury probably is not caused by these mites except when they are present in large numbers, when breathing may be hindered. Another small mite [4] sometimes feeds on the feathers of fowls but causes no apparent injury. Still another species [5] has recently been found by the writers in great numbers along the grooves on the underside of the shaft of the wing feathers of turkeys in Texas and Louisiana. Associated with this, but apparently in very small numbers, another mite [6] was taken. Neither of these caused any apparent injury to the host. Several other kinds of mites are found on various birds, as well as domestic fowls, but these are of little or no importance as parasites.

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[1] *Cnemidocoptes gallinae* Railliet.
[2] *Laminosioptes cysticola* Vizioli.
[3] *Cytoleichus nudus* Vizioli.
[4] *Rivoltasia bifurcata* Rivolta.
[5] *Freyana chanayi* Trouessart.
[6] *Megninia cubitalis* Megnin.

CHIGGERS ("RED BUGS" OR HARVEST MITES).

The chiggers which attack chickens are the same minute red mites which attack man. They are the first stage of a large red mite, which when mature is entirely harmless. Normally these immature mites are parasitic upon insects. They are often very widely distributed in fields and thus readily picked up by chickens. They attach themselves to the skin in groups beneath the wings and on the breast and neck. The injury is most severe among young chickens, although grown fowls occasionally are annoyed to some extent. Young chickens which have a free range, especially if it extends into lowlands and under trees, are very susceptible to attack. The infested chickens become droopy, emaciated, soon refuse to eat, and if exposure to the mites is continued a considerable mortality is likely to result. Intense irritation is set up, and abscesses are formed at the points where the clusters of mites are feeding. These abscesses sometimes are one-third of an inch in diameter and surrounded by a greater inflamed area. Suppuration takes place beneath the skin, and swelling around the clusters of mites causes the formation of a considerable cavity at the center where the mites are attached.

In the South and in the Central States, where chiggers are numerous, probably the best plan is to keep young chickens during the summer from ranging where these mites are likely to occur. If chickens are hatched very early in the spring, it is likely that they will escape chiggers more or less completely. When the chickens do become infested the application of sulphur ointment or kerosene and lard will destroy them. If extensive suppuration has taken place, the scab should be removed and the area washed with a 4 per cent carbolic-acid solution. Occasional light dusting of chickens with flowers of sulphur doubtless will keep these "red bugs" off, and where fenced range is infested the application of sulphur at the rate of 50 pounds per acre with a dust blower would keep them in control.[1]

LICE.

LICE ON CHICKENS.

All poultry lice or bird lice have stout cutting or biting mouth parts which distinguish them from the sucking lice of cattle and other domestic animals. Unlike the mites, lice remain on the hosts constantly. More than 40 species of lice are found on the various domestic fowls. Some species are found on one host only, while other kinds may attack a number of fowls. Chickens are infested by more kinds of lice than any other domestic fowl. Seven species are very commonly found on chickens in the United States, four or five on pigeons, two or three each on geese and ducks, three on turkeys, and several each on guinea fowl and peafowl.

All these lice are adapted to the conditions under which they live. They have a flattened form and are fitted with various spines and

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[1] Further information regarding harvest mites or "red bugs" may be had from Farmers' Bulletin 671, which may be obtained on application to the Secretary of Agriculture, Washington, D. C.

peculiarly modified legs which assist them in moving about through the feathers. Certain species which remain on the larger feathers have a very narrow, elongate form which utilizes the protection afforded by the grooves between the barbs of the feathers. In fact, poultry lice show a wide divergence in size, shape, and spiny armature.

FOOD HABITS AND INJURIOUSNESS.

Poultry lice are not fitted for sucking blood. They feed on portions of the feathers or on scales from the skin, and their presence in any considerable numbers is responsible for serious injury.

In the Southern States the loss due to lice probably is greatest among young chickens. Chickens hatched after April 1 and brooded by hens experience a high mortality, much of which appears to be due directly or indirectly to lice. Early chickens also are sometimes affected. The lice often leave the hens and pass to the chickens before these become dry after emerging from the shell.

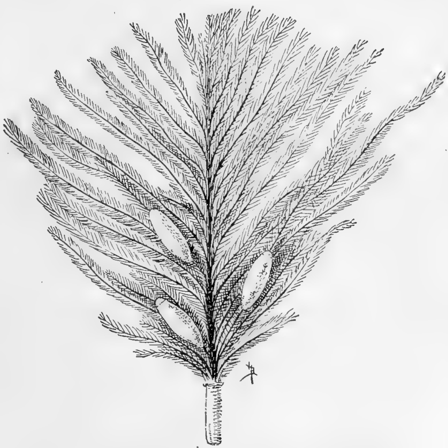

FIG. 7.—Eggs of the head louse (*Lipeurus heterographus*) on feather. Greatly enlarged. (Original.)

The first symptoms of lice infestation usually are droopiness, lowered wings, and ruffled feathers. Diarrhea follows, and the chickens then often die in a few days, or, when older, sometimes fall a prey to various diseases. Grown fowls sometimes may be very heavily infested with lice without showing any ill effects, but in such cases the egg yield is likely to decrease. In other cases the fowls may lose weight and sometimes die as a result of the lice or succumb to some of the common chicken maladies.

Turkeys suffer to a considerable extent when young, and no doubt poults frequently are killed by gross infestation. Older birds do not seem to be so badly affected. This is also true of ducks and geese. In general, these fowls are less heavily infested with lice than chickens.

KINDS OF LICE ON CHICKENS.

The seven different species of lice common on hens are spoken of as body lice, head lice, and feather lice, according to the usual places in which they are found, but since the different species intermingle to a considerable extent, it is not possible to separate them absolutely on this basis. The writers have observed that the relative number of lice of the different species varies much in different flocks in the same neighborhood, and even in the same flock some chickens often have one species predominating, while others have another. Usually three or more species are to be found on an infested fowl.

THE HEAD LOUSE OF CHICKENS.[1]

This species is primarily a head louse, although occasionally found on the neck and elsewhere. It is undoubtedly the most injurious species to young chickens, as many of the other forms which are serious annoyers of grown poultry do not thrive well in the down on chicks. It is a dark grayish species nearly one-tenth of an inch in length, and may be found on the top or back of the head, behind the ears, or beneath the bill. Usually it is located close to the skin with its head very close to or against the skin of the chicken, the body extending away from the skin on the down or along the feathers. The eggs are deposited singly on the down or small feathers about the head. Eggs attached to a small feather are shown in figure 7. These hatch in four or five days into minute semitransparent lice which resemble the adult in shape. After molting the skin several times, and in the meantime increasing in size and becoming darker in color, the lice reach the adult stage in about 17 to 20 days. The male of this species is shown in figure 8.

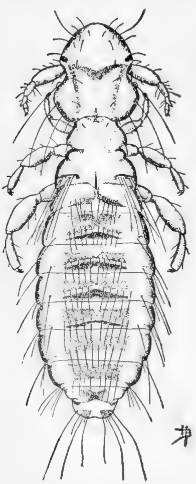

FIG. 8.—Head louse: Male, top view. Greatly enlarged. (Original.)

Despite the fact that this louse confines its attack principally to the head, it passes readily from one chicken to another and from the mother to her young. This is the species against which the poultry man must guard his young chickens. The treatment recommended for various lice (p. 22) is satisfactory for this species. It is essential that the applications be made to the regions about the head to destroy it on grown fowls, and on young chickens this is the only region which requires attention. After young chicks are fairly well feathered the head louse decreases in number, probably because conditions are less favorable for breeding and because the older chickens scratch the infested parts more vigorously. The number of head lice may increase again after the chickens become adult.

THE BODY LOUSE OF CHICKENS.[2]

The common name "body louse" is aptly applied to this species, and refers to its habit of remaining on the skin of the fowl rather

[1] *Lipeurus heterographus* Nitzsch.

[2] *Menopon biseriatum* Piaget.

than on the feathers. It does not always confine itself to the body, sometimes being taken on the head, neck, and legs. It favors those portions of the skin which are not densely feathered. On chickens it is partial to the region just below the vent, but in heavy infestations it is abundant on the breast, under the wings, on the back, and also on the head, neck, and thighs. When the feathers are parted it is seen running rapidly upon the skin to seek protection. With young chickens it is more abundant on the back than around the vent.

This louse is rather large and robust, straw yellow in color, with some dark spots due to food within the digestive tract. The two sexes are shown in figures 9 and 10.

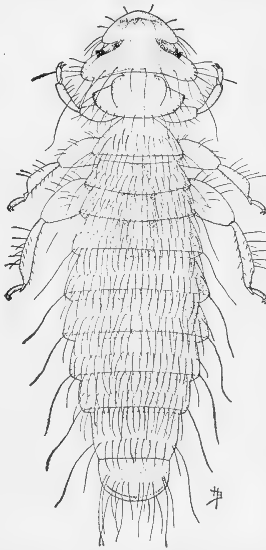

FIG. 9.—Body louse (*Menopon biseriatum*): Male, top view. Greatly enlarged. (Original.)

The body louse is probably the most injurious species on grown chickens, but it also infests young fowls, sometimes seriously. As it remains on the skin of the host, irritation is kept up constantly. Often a marked reddening of the skin of the fowl in the regions most heavily infested results, and in some cases scabs and blood clots are formed.

The eggs are deposited in clusters on the base of the feathers, usually being attached to the lowest barbs along the shaft. They are most abundant on the small feathers below the vent, where the masses of eggs sometimes become very large—fully half an inch in length. As the lice continually add eggs, the masses are extremely large when seen several months after molting. In the case of young fowls the eggs are often deposited in numbers on down or small feathers and on hairs about the head and throat. A mass of eggs of this species is shown in figure 11.

The eggs hatch in about a week, and the adult stage is reached from 17 to 20 days after the eggs are deposited. This louse has a short period of growth both in summer and in winter; hence fowls which are not actively fighting the louse become swarming with them in a very short time. Fortunately the heat of the body is necessary for the hatching of the eggs, and the lice themselves die in a very short time when off the fowl. For this reason little attention need be given to lice and eggs which are shed by the host during molting or at other times. This point, as well as methods of control, is discussed in later pages.

The body louse appears to pass readily from one fowl to another when they are closely associated. It also infests turkeys, upon which it multiplies to some extent, and it is said to occur on pigeons, but has not been found on them by the writers

THE SHAFT LOUSE.[1]

The shaft louse is the species spoken of by most authors as the "small body louse," a name which does not fit the habits of the species. Normally, it occurs along the shaft of the feathers and does not remain on the body of the host for any length of time. The shaft louse is closely related to the large body louse and resembles it somewhat. It is smaller, rather lighter yellow in color, and somewhat less spiny. (See fig. 12.) The habits of the shaft louse will enable one to separate it readily from the large body louse. When the feathers on the thighs or breast are parted this louse will be seen running toward the body along the shaft of the feather. Sometimes as many as a dozen lice will be seen, one behind another, along the feather shaft.

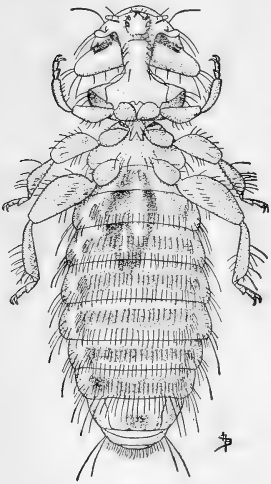

FIG. 10.—Body louse: Female, underside. Greatly enlarged. (Original.)

Although this species is probably the most common found on chickens in various parts of the country, the writers consider it of much less importance than the body louse, chiefly because it stays on the feathers the greater part of the time and probably feeds exclusively on the barbs of the feathers and on scales along the shaft. It is not known to occur on young chickens. Seemingly the absence of feathers prevents the successful development of the species on young fowls.

The eggs are deposited singly at the base of the feathers, hidden between the main shaft and the after shaft. It appears that eggs of the shaft louse require more time for incubation than those of the head louse or the body louse, and the time required to reach maturity is also greater. The shaft louse appears to live much longer on feathers which have dropped from the host than any other species on domestic fowls.

[1] *Menopon pallidum* Nitzsch.

Several kinds of domestic fowls harbor the shaft louse, but it has not been shown that they will breed successfully on fowls other than the chicken. It has been found on the guinea fowl and on turkeys and ducks closely associated with chickens.

FIG. 11.—Mass of body louse eggs attached to feather. Greatly enlarged. (Original.)

THE WING LOUSE.[1]

This species has been called the "variable louse," but the variations are not apparent to the ordinary observer, and the writers suggest "wing louse" as a common name. This is the only species found commonly on the large wing feathers of chickens. It is seen at times also on the neck hackles, tail, and back feathers.

The wing louse, which is related to the head louse, is dark gray and has an elongate body. It is more slender than the head louse, however, and rather darker in color. Most easily seen on white fowls, it is found in all situations, but especially along the underside of the primary wing feathers. It is a sluggish species and often lies between the barbules of the feathers near the shaft without showing any life. The elongate white eggs are laid between the barbules of the large feathers.

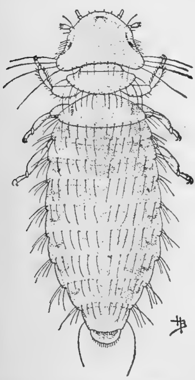

FIG. 12.—Shaft louse (*Menopon pallidum*): Female, top view. Greatly enlarged. (Original.)

OTHER LICE OF CHICKENS.

Three other species of lice are found more or less commonly on chickens. The species to which the writers have applied the common name of "fluff louse"[2] is very small but broad, pale in color, with translucent appearance. It is common on fowls, but seldom abundant, and is of little importance. It is found on the fluff of the feathers on various parts of the bird, but is most abundant where the feathers are fluffiest. Usually it hangs to the loose barbs on these feathers some distance from the shaft and shows little activity.

The large hen louse [3] is less abundant than the fluff louse. When present, it is easily recognized by its very large size and striking

[1] *Lipeurus variabilis* Nitzsch. [2] *Goniocotes hologaster* Nitzsch. [3] *Goniocotes abdominalis* Piaget.

appearance. It is nearly an eighth of an inch in length and very broad in proportion, as shown in figure 13. The color is smoky gray to almost black, with darker marks on the sides of the abdomen. It occurs on the feathers on various parts of the chicken's body and is remarkably agile for its size. Some call it the "blue bug," hence it has become confused in certain instances with the chicken tick, for which the name blue bug is generally used.

The brown chicken louse [1] has not been reported to occur in America heretofore. The writers have taken it in several instances on chickens in the vicinity of Dallas, Tex., and Orlando, Fla. This indicates its presence in much of the South. It is somewhat smaller than the large hen louse and reddish brown in color. It is found on the feathers of the body. None of the three species last discussed has been taken by the authors on young chickens.

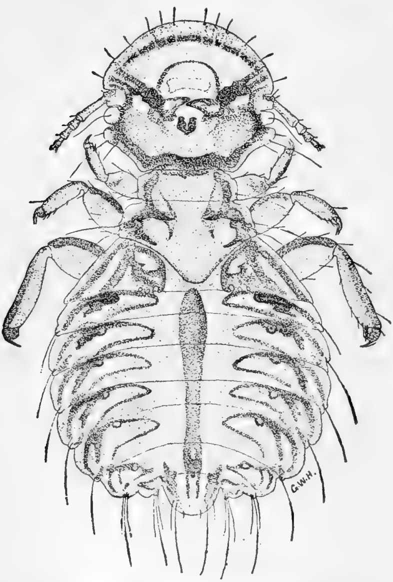

FIG. 13.—Large hen louse (*Goniocotes abdominalis*): Male, top view. Greatly enlarged. (Herrick.)

LICE ON TURKEYS.

Four species of lice are commonly found on turkeys in this country. One of these, which occurs particularly on turkeys associated with chickens, is the common body louse of chickens. The writers have not found this species in great numbers on turkeys, but it sometimes becomes sufficiently abundant to cause considerable irritation and doubtless is injurious both to the grown fowls and to the young. The shaft louse of chickens also has been found on turkeys, but probably does not breed on that host. The other two species seem to be native to the turkey, probably existing on this fowl in the wild state. The large turkey louse [2] (fig. 14) probably is most abundant. It occurs on the feathers on various parts of the body, especially on the neck and breast. The slender turkey louse [3] is a species of good size, though rather elongate, resembling in shape the head louse of chickens. Normally neither of these species is excessively abundant

[1] *Goniodes dissimilis* Nitzsch. [2] *Goniodes stylifer* Nitzsch. [3] *Lipeurus polytrapezius* Nitzsch.

but on crippled or unthrifty turkeys they may cause serious annoyance and undoubtedly they are injurious to poults.

For remedial measures see pages 20–27.

LICE ON GEESE AND DUCKS.

While considerable numbers of lice are found on domestic geese and ducks, they seldom become sufficiently numerous to cause noticeable injury. One of these species [1] is quite common on ducks throughout the country, and a variety of this same species is to be found on the goose. A slender species [2] has been found by the

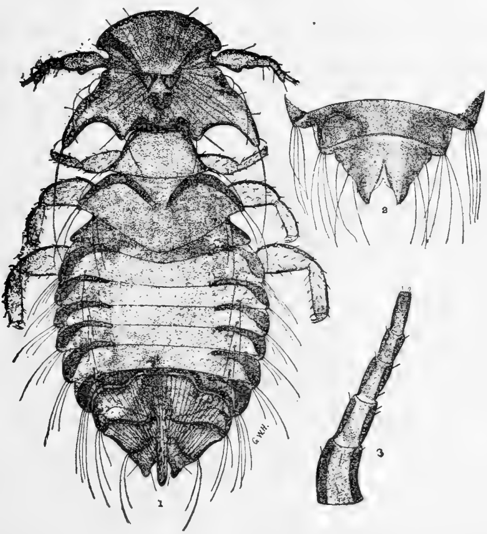

FIG. 14.—Large turkey louse (*Goniodes stylifer*): *1*, Male, top view; *2*, tip of abdomen of female; *3*, antenna of female. All greatly enlarged. (Herrick.)

writers rather commonly on the duck in the vicinity of Dallas, Tex., and in other parts of the United States. Another louse similar in form, but which appears to be new to science, has been collected on these hosts in Mississippi. Both of these species inhabit the wing feathers and are often very numerous at the base of the large feathers of the wing. Young ducks which have been hatched by hens are sometimes much annoyed by the head louse, which attacks them in the same way as it does young chickens.

The same control measures recommended for chicken lice will destroy these insects on ducks and geese.

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[1] Known scientifically as *Docophorus icterodes* Nitzsch. [2] *Lipeurus temporalis* Nitzsch.

PIGEON LICE.

Considerable annoyance to pigeons has been reported by poultrymen in different parts of the country. While a number of species of lice have been reported as occurring on pigeons, most of the trouble seems to be due to the slender pigeon louse [1] and the broad pigeon louse.[2] The former sometimes occurs in great numbers, attacking both the old birds and the partially feathered squabs.

For measures of control see the discussion of this subject in subsequent pages.

LICE OF THE GUINEA FOWL AND PEAFOWL.

The guinea fowl and peafowl are both subject to the attack of several species of lice. Most of these are of kinds different from those found on the common chicken and other domestic fowls, but the guinea fowl has been found to become infested with four of the species found on the chicken. It does not appear that either of these hosts is materially injured by lice, but it is necessary to bear in mind the risk in allowing guinea fowl to remain untreated when eradicating lice from other poultry on the same farm.

CONTROL OF POULTRY LICE.

It has been generally felt that poultry lice are more or less a necessary evil and that the best that can be expected is to keep them in control by repeated treatment. A few have attempted, with varying degrees of success, to start with clean premises and clean fowls and keep them free from vermin. This is most feasible in the case of persons going into the poultry business on a rather extensive scale and with entirely new equipment (see page 28). For the average farmer and the poultryman already established the situation has resolved itself largely into a fight against the various pests already present.

There is no fundamental reason why a flock should not be entirely freed from lice and maintained in this condition. Reinfestation comes principally from stray fowls which gain access to the poultry yards and from purchased stock added to the flock. Stray fowls can not always be excluded, but in the case of added stock it is advisable to treat all chickens, old or young, when they are first brought on the premises.

The time of year for starting a campaign against lice is another point to be considered. The writers would favor the treatment of the entire flock during the late summer or early fall. At this time of the year weather conditions usually are favorable to dipping, most of the young fowls are well matured, and much of the superfluous stock has been disposed of, so that there are fewer birds to treat.

[1] *Lipeurus baculus* Nitzsch.

[2] *Goniocotes compar* Nitzsch.

Since there is very little danger of reinfestation from lice on molted feathers, the question of avoiding the molting period is not a serious one, yet, if the treatment can precede molting it probably would be better.

If the fall treatment has been neglected it is imperative that the flock be cleaned of lice before brooding time in the spring. Usually this would mean that the dusting method would have to be followed on account of adverse weather conditions. Treating the birds at this time will insure their vigor as well as undisturbed brooding, which is necessary to successful hatching, and, what is more important, the infestation of the young chickens will be avoided. Although lice normally stay upon the host continuously and do not have the habit of hiding away in cracks about buildings, yet the poultry houses and runs should be well disinfected occasionally, especially as action against mites is necessary if these are present. It is well to make this general clean-up at the time the flock is treated for lice. This minimizes any danger of reinfestation.

On large poultry farms the complete eradication of lice is often complicated by inability to control the fowls. When proper pen construction is at hand, it is possible to treat a pen or two a day until the entire flock is covered. The more rapidly treatment progresses the better, of course, and great care should be taken to avoid the escape of fowls from infested to uninfested pens.

SODIUM FLUORID EFFECTIVE AGAINST ALL LICE.

The writers have tested a number of the materials most generally advocated for lice destruction and several new compounds which it was thought might be effective. In this series of tests nothing else was found to be as satisfactory as sodium fluorid. The experiments have demonstrated that this chemical is exceedingly poisonous to all species of chicken lice. It kills both adults and young, including the young which emerge from the eggs present at the time of treatment.

Sodium fluorid can be obtained in two forms, known as commercial and as chemically pure. Both of these are in a dry state, the former being a dry powder and the latter consisting of small crystals somewhat lumpy. While the chemically pure material is effective, it is not as easily applied by the dusting method as the more finely powdered commercial form, and, furthermore, it is higher in price. The commercial grade should contain 90 to 98 per cent sodium fluorid.

This material is the sodium salt of the chemical element known as fluorin and hence is a compound very similar to ordinary table salt, which is known chemically as sodium chlorid. In asking for sodium fluorid it is therefore important that the name "fluorid" be carefully stated to the druggist. Up to this time the demand for the material has been very limited. Prior to the work of the writers its only known insecticidal use was against cockroaches, for which it has been demonstrated to be very effective. Owing to this limited demand the material is not ordinarily found in drug stores. Druggists, however, can obtain it readily from manufacturing chemists in the larger centers, and with demand it will be carried in stock by many local dealers. The commercial sodium fluorid at present prices should be retailed at from 30 to 60 cents per pound, the price varying somewhat with the amount ordered by the druggist and the distance from the chemical manufacturing centers.

Sodium fluorid in a dry state does not deteriorate quickly. It should be kept in a dry place either in bottles with stoppers or in closely covered cans. In this condition it will remain active indefinitely.

METHODS OF APPLICATION.

In treating poultry with sodium fluorid, *if proper methods are followed, a remarkable degree of control is obtained. One application of sodium fluorid to all fowls on given premises will completely destroy all lice present.*[1] It is essential to make sure that the treatment is thorough and that every fowl is treated, for if one infested chicken escapes it will in a short time reinfest the entire flock and thus make it necessary to do the work over at a considerable loss of time and money.

Sodium fluorid may be applied in two forms, as a dust and as a dip. In using either form the first step is to see that all fowls are shut in the poultry house or placed in coops prior to beginning treatment.

DUSTING.

The action of sodium fluorid when applied in dust form is comparatively slow; hence, if fowls are examined the day following treatment, or even two or three days later, some lice may be found. The material persists, however, and after four or five days all lice disappear. Apparently the hatching of the eggs is not prevented, but the young lice find sufficient material present in the feathers upon emerging from the eggs to destroy all of them.

For complete destruction of lice it is essential that small amounts of the material be placed on different parts of the infested birds. Contrary to the usual belief, all species of lice do not migrate freely from one part of the bird to another, hence the material must be well distributed to bring it in contact with all lice present.

The writers have found what they term the "pinch method" to be entirely effective against all lice and to have the advantage of economy of time and material. When the material is applied by this method (see illustration on title-page) it is placed on a table in an open vessel, and the fowl is held by the legs or wings with one hand, while with the other hand a small pinch of the chemical is placed

[1] As an example of complete eradication, a flock of 150 Wyandottes treated by the owners at Raymond, Ill., in November, 1917, was found to be absolutely free of lice in April, 1919.

among the feathers next to the skin about as follows: One pinch on the head, one on the neck, two on the back, one on the breast, one below the vent, one on the tail, one on either thigh, and one scattered on the underside of each wing when spread. Each pinch can be distributed somewhat by pushing the thumb and fingers among the feathers as the material is released. It is advisable when dusting to hold the chicken over a large shallow pan, as in this way the small amount of material ordinarily lost is recovered.

The material may be applied by means of a shaker, but this method has some disadvantages as compared with the pinch method. Small nail holes are punched in the bottom of a can, which is provided with a close-fitting lid on the other end. The material is then shaken into the feathers with one hand, while the feathers are opened with the other. This necessitates the presence of a second person to hold and turn the fowl. When this method is followed the amount of sodium fluorid used may be reduced by adding four parts of some finely powdered material, such as road dust or flour, to each part of the chemical. If the material is employed alone, somewhat more of it is used than by the pinch method, and more or less dust floats in the air, which causes irritation of the throat and nose. This can be avoided largely if the operators wear dust guards over the nose or keep pieces of wet cloth over the nose and mouth. Care should be taken to avoid the burning effects of the chemical on the hands of the operator.

Although the writers have not applied this material with a dusting machine or revolving barrel, they are of the opinion that this would not be thorough, might bruise the fowl, and would be irritating to the air passages of the birds.

For lice on young chickens, young turkeys, and, in fact, all newly hatched fowls the application of sodium fluorid in the dust form is recommended, rather than by dipping. This applies also to sick fowls.

It is important in using sodium fluorid on young chicks to treat them in the morning rather than just before they go to roost. Only two pinches are needed for each chick provided the mother is properly dusted. One of these should be distributed on the neck, top of head, and throat and the other on the back and below the vent. It has been found that there is no injury to eggs provided a sitting hen is properly treated.

The application of sodium fluorid to pigeons by the dust method, using about five pinches to each pigeon, has been found effective, but for complete eradication dipping should be practiced.

DIPPING.

There seems to be a general sentiment among poultry raisers against the practice of dipping fowls. This is probably partially on account of the fact that the dips tried have been of an oily or caustic nature and have tended to soil the feathers and in some cases injure the skin of the fowl and give the feathers a thorough wetting. The experience of the writers does not justify this aversion when dipping in a sodium-fluorid solution. It may be said that in general the dipping method is most applicable to the Southern States and to summer treatments in the north. The first requisite is a rather warm sunny day, so that the fowls will dry quickly. Windy weather should be avoided. In dipping fowls as described below, the feathers do not get thoroughly wet, and if the operation is finished an hour before sundown the fowls will become thoroughly dry before going to roost. In rather extensive tests of this method the writers have observed no ill effect whatever from the dipping. As compared with dusting, this method has an advantage in that it reduces considerably the cost of materials, is more rapidly done, and the discomfiture to the operator is avoided. It is just as effective as dusting.

The lice die much more quickly following dipping than when sodium fluorid is applied in dust form. It appears that all those which are touched by the liquid die very promptly, and the others succumb in a few hours.

In using the dipping method all that is necessary is a supply of tepid water and a tub. If two persons are to dip at the same time it is advisable to use a large tub. The water should be measured into the tub and three-fourths to 1 ounce of commercial or two-thirds of an ounce of chemically pure sodium fluorid added to each gallon of water. It is readily dissolved by stirring. The tub should be filled to within 6 or 8 inches of the top, and as the amount of solution is lowered through dipping numbers of fowls, water with the proper proportion of sodium fluorid dissolved should be added from time to time. In dipping the fowls it is best to hold the wings over the back with the left hand and quickly submerge the fowl in the solution, leaving the head out while the feathers are thoroughly ruffled with the other hand so as to allow the solution to penetrate to the skin on different parts of the bird. The head is then ducked once or twice, the bird is lifted out of the bath and allowed to drain a few seconds and is then released.

It is not necessary to keep the fowl under the water longer than 20 to 30 seconds and the head only an instant.

Owing to the fact that pigeons are so closely feathered it is necessary to add about three-fourths to one ounce of laundry soap to each gallon of water in order to increase the penetration of the dip. A thorough dipping of the pigeons in this way, ruffling the feathers while the birds are under the water, will destroy all lice.

EFFECT OF SODIUM FLUORID ON FOWLS AND MAN.

Fortunately this compound is very destructive to lice without producing any ill effects on the chickens. No skin irritation or injury to the condition of the feathers has been observed in the large number of domestic fowls used in experimental work, when either the dusting or the dipping method was used. In fowls that are being dusted there is occasionally some temporary irritation of the air passages, as evidenced by labored breathing and sneezing. This effect is not noticeable a few minutes after treatment.

Caution is necessary to prevent the sodium fluorid when used in dust form from gaining access to the food and water of the fowls, and to empty out sodium fluorid solution where the chickens can not drink it before it soaks into the ground. It should be remembered that the material is rather poisonous if taken internally.

Where some of the sodium fluorid in the dust form reaches the body of the operator and is allowed to remain for a number of hours, as may be the case when several hundred fowls are dusted, local irritation and burning may occur on tender portions of the skin. In dusting large flocks it is therefore advisable to do the work on a table rather than to hold the fowls between the knees as is sometimes done. The solution does not injure the hands, even when dipping is continued for a number of hours, except in cases where sores are present which may become slightly irritated.

Precaution should be taken not to allow sodium fluorid solution to remain in galvanized vessels any great length of time. In fact, it is best not to keep it over night in tubs or galvanized containers, as it will injure them.

COST OF APPLICATION.

One pound of commercial sodium fluorid, when applied by the "pinch method," will treat approximately 100 hens; thus at a cost of 40 cents per pound the expense for material will average less than one-half cent per fowl. It has been found by actual practice in treating several hundred fowls that an average of from two to three minutes is required for treating each fowl, one man doing the work. This includes the time necessary for catching the birds as well as dusting them. The dusting itself occupies about one to two minutes. Of course, the time involved in catching them would vary in every individual instance according to conditions. Using the above figures as a basis, and figuring a man's time at 30 cents per hour, it would cost approximately, $1.65 to treat 100 fowls by the pinch method.

When the dust can is used the amount of material is usually double and the average time per bird is somewhat increased.

By the dipping method the amount of the material is considerably reduced, especially if large flocks are to be treated at one time. Over 800 fowls have been dipped at one time, an average of 5.2 ounces of sodium fluorid to 100 fowls being used, which at the same figure would cost 13 cents. The labor involved is also thus reduced. The average time for catching and dipping the birds was about one and three-fourths minutes per fowl, one man working. This makes a cost of labor, as above computed, of about 87 cents per hundred fowls and a total cost for material and labor of about $1. This reduces the cost so that it is within the reach of every one, especially when it is considered that ordinarily much time is occupied in fighting lice without accomplishing that complete destruction which would result from a single treatment as above outlined.

OTHER REMEDIES FOR LICE.

While the use of sodium fluorid is advised in all cases, it may be stated that one application of flowers of sulphur when applied thoroughly in dust form has been found to destroy all stages of several species of lice experimented with. In a few instances, however, some lice remained on the fowls after treatment. This was attributed to the difficulty of getting the dust over every portion of the fowl but at the same time it shows that exceedingly thorough and careful application of sulphur is required to secure complete destruction. About four days are required for the fowls to be freed of living lice. The ready availability of flowers of sulphur and its comparatively low cost per pound tend to recommend it for this use. Furthermore, it is not disagreeable to handle.

A number of poultry raisers, however, have stated that injury to the fowls sometimes results from the use of sulphur, although the writers have seen no injury further than a very slight scaling of the skin following treatment. It is possible that the injury observed by some was due to mixing the sulphur with grease or other substance. To accomplish complete destruction the writers have found it necessary to use considerable quantities of sulphur, averaging about 6 pounds per hundred fowls, which at 10 cents per pound would make a cost of 60 cents for the material. The expense of application would be about one-half greater than that given for the use of sodium fluorid by the pinch method, as it is necessary to apply the sulphur with a dust can. The total expense would therefore be greater than by using sodium fluorid by the pinch or the dipping method.

The writers have found also that dipping fowls in a soap solution made by dissolving 1 ounce of laundry soap in a gallon of water will destroy all lice present, but a second dipping 10 days later is necessary in order to destroy the lice that have hatched from eggs which are not killed by the treatment. This soap solution causes a complete wetting of the feathers, and hence there is no doubt danger of producing colds when the weather is unfavorable. It should be used only during favorable weather.

A great number of remedies are in general use in this country, only a few of which can be mentioned here. A mixture of crude carbolic acid, gasoline, and plaster of Paris is quite effective in reducing the number of lice, but experiments have shown that at least two, and perhaps more, applications are necessary to destroy all lice.

Mercurial ointment or blue ointment has also been advised. It has been found that the use of this material as recommended will greatly reduce the number of body lice but has little effect on the head and wing lice. When several times the amount usually recommended is applied to a number of places on a fowl it is quite effective, but the cost of the material and treatment is greater than in the case of sodium fluorid, the use of greasy material is objectionable, and burns result.

A number of other compounds, many of which contain pyrethrum, are advocated. These also fail to accomplish complete destruction of the lice. For head lice on young chickens carbolated petrolatum applied in small quantities has been found quite satisfactory. Medicated nest eggs, said to control poultry lice, are on the market. For the most part these consist largely of naphthalene. While this material will destroy lice when applied generally to the fowl, it is markedly injurious to the hen's eggs as well as to the bird. If used in quantity, or if the medicated eggs are allowed to remain for a considerable length of time beneath a hen, she may die as a result.

SUPPLEMENTAL CONTROL MEASURES FOR ALL PESTS.

Chickens will not give adequate returns in eggs or growth when kept under insanitary conditions. The construction of the poultry house should receive first attention. Adequate air space, lighting, and ventilation should be provided, and the entire house should be cleaned out at frequent intervals. While these things can not be depended upon to control mites and lice, they aid the poultryman in determining when these pests are present, and, furthermore, the fowls are kept in vigorous condition, which in itself is conducive to the control of various pests. Diseased fowls, or those with malformed bills or feet, fall ready prey to lice, mites, and other insect pests. The suggestions given in previous pages for the construction of roosts and nest boxes should be followed, even though the buildings are new and otherwise properly arranged.

DUST BATHS.

While it is well to provide a good dust bath for chickens, it can not be depended upon for louse and mite control. It is far better to eradicate the pests completely. The main difficulty about depending upon dust baths for lice is that some fowls seldom dust themselves, and those which dust freely never free themselves completely. The dust bath should be kept under cover and may consist of fine road dust with coal ashes added.

A METHOD OF AVOIDING POULTRY PESTS.

It is possible for a prospective poultryman to avoid having to contend with most poultry parasites by selecting a site which is fairly well isolated from other poultry. He should first securely fence the site and construct new buildings and runs. He should start with incubator chickens hatched on the premises and never bring any fowls on the place. Second-hand crates should not be brought on the farm unless carefully disinfected beforehand. The possibility of insects being carried from infested quarters on clothing, wagons, etc., should be kept in mind, as well as the possibility of their carriage by sparrows.

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The Principal Household Insects of the United States. (Entomology Bulletin 4, n. s.) 1896. Price 10 cents.
Insects Affecting Domestic Animals. (Entomology Bulletin 5, n. s.) 1896. Price 20 cents.

Notes on Mosquitoes of the United States. (Entomology Bulletin 25, n. s.) 1900. Price 10 cents.

Notes on "Punkies." (Entomology Bulletin 64, Pt. 3.) 1907. Price 5 cents.

Information Concerning the North American Fever Tick, with Notes on Other Species. (Entomology Bulletin 72.) 1907. Price 15 cents.

Economic Loss to the People of the United States through Insects which Carry Disease. (Entomology Bulletin 78.) 1909. Price 10 cents.

Preventive and Remedial Work against Mosquitoes. (Entomology Bulletin 88.) 1910. Price 15 cents.)

The Rocky Mountain Spotted Fever Tick with Special Reference to the Problem of its Control in the Bitter Root Valley in Montana. (Entomology Bulletin 105.) 1911. Price 10 cents.

The Life History and Bionomics of Some North American Ticks. (Entomology Bulletin 106.) 1912. Price 30 cents.

FIVE MEN IN SIX DESTITUTE AT 65.

Old age brings to all a decrease, and to most an entire loss, of earning power. During this period we either depend upon what we have accumulated during our earning period or upon the assistance of relatives or the State.

Life insurance actuaries have estimated that at 65 years of age some 64 men of each 100 who attain the age of 25 are still living. Of this number 1 is rich, 4 are wealthy, 6 are self-supporting and compelled to work for a living, and 53 are dependent upon children, relatives, or charity.

This is the situation in America. It is not true in some other countries, notably France.

The Government, through the Savings Division of the Treasury Department, is actively interested in promoting a spirit of thrift in America. In furthering this purpose it issues an unusually attractive Government security in the form of the War Savings Stamp, which is well adapted to the use of those who wish to accumulate a fund for old age.

Persons who build up such a fund must save systematically. Investment in War Savings Stamps enables them to put these savings to work at once at a rate of interest especially attractive when the period of accumulation may run over a comparatively long period.

If at 25 a man begins to accumulate a fund for old age by hiding somewhere a dollar a week, he will have $2,080 when he is 65 years old. If he buys War Savings Stamps at the rate of a dollar a week and keeps at it, he will be absolutely certain to have over $5,100 at that time.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1919

APHIDS INJURIOUS TO ORCHARD FRUITS, CURRANT, GOOSEBERRY AND GRAPE

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and

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FARMERS' BULLETIN 804

UNITED STATES DEPARTMENT OF AGRICULTURE

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

Washington, D. C. April, 1917

APHIDS are small, delicate, winged or wingless insects which feed upon plant juices, draining them from the foliage, fruit, twigs, or roots, through a beak pushed into the plant tissues.

Many kinds injure orchard fruits, currant, gooseberry and grape. The most important are discussed in this bulletin.

Contact sprays, such as kerosene emulsion, soap washes, nicotine solutions, etc., must be used to kill aphids. Directions for preparing and applying them will be found on pages 34–39.

Stomach poisons, such as arsenate of lead, Paris green, and other arsenicals, are of no use against aphids.

Species which winter in the egg stage on the plants to be protected may be sprayed early in the spring as the buds are expanding, to kill the first brood and insure against injury later in the season.

Leaf-curling species, especially, should be treated with this bud spray in years when they are expected to be abundant. They can not be reached satisfactorily after the leaves have unfolded and the aphids have begun to be troublesome.

Those species which do not curl the leaves may be controlled readily by sprays when they are noted as becoming numerous.

Annual bud spraying in the case of the apple appears to be good orchard practice and, continued for a series of years, doubtless would prove profitable.

APHIDS INJURIOUS TO ORCHARD FRUITS, CURRANT, GOOSEBERRY, AND GRAPE.[1]

CONTENTS.

The control of aphids, or plant lice, is an ever recurring problem to the grower of orchard and bush fruits. Although cereal and forage crops furnish perhaps the most striking examples of the destruction wrought by aphids, practically no crop is free from attack by one or more of these small and delicate insects. During the past decade especially, aphid injury to orchard fruits, particularly the apple, has been on the increase.

The present bulletin treats of the aphids injurious to fruit and foliage of apple, quince, pear, plum, cherry, peach, currant, gooseberry, and grape. Thirty-two species of aphids in all are discussed. The more important forms affecting a given fruit are considered first, and then follows a brief account of species known to infest the plant locally or occasionally, and which growers should be able to distinguish from the more destructive species. In their life history aphids are peculiar in many respects, and each species occurs in several different forms; for this reason a short account of aphids in general is given for the information of readers not familiar with these facts. Remedial measures are described at the close of the bulletin, since similar treatments are applicable, with some variations, for the control of all the species considered.

[1] Since the well known grape phylloxera [*Phylloxera vitifoliae* (Fitch)] is injurious principally to the roots and requires control measures radically different from those employed against foliage-inhabiting aphids, it is mentioned only incidentally in this bulletin, although its galls on grape leaves are illustrated (fig. 23, p. 32).

NOTE.—This bulletin is of interest to orchardists, vineyardists, and growers of currants and gooseberries in all parts of the United States.

APHIDS IN GENERAL.

Aphids, or insects of the family Aphididae, have a development which is remarkable in several ways. Eggs laid in the autumn hatch in the spring about the time when vegetation revives. From these winter eggs is produced a generation of females, usually wingless, which reproduce without the intervention of males (agamic reproduction), many species giving birth to living young. The adult aphids of the first generation are termed stem-mothers. The offspring of the stem-mothers (second generation) may be winged or wingless, or both forms may occur. They reproduce without the intervention of males, some species being oviparous, or egg laying, and depositing eggs which do not require fertilization for development, while others are viviparous—that is, they bring forth young alive, the eggs developing and hatching within the body of the parent.

A succession of generations may be produced in this way until the approach of autumn, when the true sexes appear and the females deposits eggs; or a species perhaps may be more or less biennial, some individuals producing true sexes only every second year. In still other species, the true sexes of which are at present unknown, reproduction without the intervention of males continues for a series of years.

The same species of aphid usually exhibits several forms, as wingless agamic females, winged agamic females, and the true sexual forms. In the last the male may be winged and the female wingless, or both sexes may be wingless. The different generations of a given species may vary more or less in appearance, and in some instances this is the case to such an extent that they appear to belong to distinct species.

Aphids feed upon sap which is sucked up through a beak pushed down into the tissues of the plant. Their presence on plants frequently is indicated by a curled and distorted condition of foliage, though this is not always so. When the insects are abundant the drain upon the plant is very great, interfering with its proper growth and development, and in extreme cases causing the death of infested parts. The leaves and shoots of plants infested by aphids are frequently seen to be covered with a black substance, as if dusted with soot. This is due to a black fungus which grows on the "honeydew" excreted by the aphids and is not especially injurious, though often objectionable as marring the appearance of the plants and fruit. Honeydew may be produced in such quantities as to coat the leaves and is attractive to various species of ants and wasps, which are often seen attending the aphids or frequenting plants infested by them. The ants of themselves are not usually the cause of trouble but merely denote the presence of the aphids.

Since frequent reference must be made in the following pages to the different stages and forms of aphids, information concerning these is presented in summary form as far as present purposes require:

Winter eggs.—These are small, oval, and blackish, and occur on the twigs, around buds, under scales of bark, or elsewhere on the shoots or branches of the winter host plant.

Stem-mothers.—The aphids hatching from the winter eggs. They are the progenitors of the numerous generations which follow during the succeeding spring, summer, and fall.

Wingless viviparous females.—Wingless aphids which give birth to living young without the intervention of males.

Winged viviparous females, or migrants.—Wingea aphids which give birth to living young without the intervention of males and which migrate to other plants, establishing new colonies. Spring migrants and fall migrants are often to be distinguished.

The true sexes.—Males and sexual females are usually developed in the fall from the viviparous forms, the female depositing eggs to carry the species over the winter.

APPLE APHIDS.

Three or four species of aphids commonly attack the fruit and foliage of the apple, while a few more, which at present are of minor importance, are known to infest this plant. The important species to be considered are the rosy aphis, the green apple aphis, the woolly aphis, the oat or European grain aphis, and the clover aphis.

THE ROSY APHIS.[1]

The rosy aphis infests especially the foliage surrounding the blossom or fruit clusters, and causes the leaves to curl badly. (Fig. 1; fig 2, *b;* illustration on title-page.) The insects when abundant also infest the fruit stalks and newly set fruit. The little apples on the infested fruit spurs often fail to thin out, remain small, and as the season progresses become knotty and distorted according to the degree of infestation. In the fall these "aphis apples" (fig. 3) may be much in evidence, especially on the lower parts of the tree, during worst aphid seasons amounting to from 15 to 30 per cent of the crop. This species is very generally present in the apple-growing portions of the country and is at present the most important aphid pest attacking the foliage and fruit of this crop. On very young trees the feeding habits differ somewhat in that in addition to the foliage the aphids may attack the young shoots, causing these as they grow to become curled and twisted (fig. 2, *c;* fig. 4), resulting in permanent deformities which in pruning must be cut out in order that a properly formed tree may be produced.

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[1] *Aphis malifoliae* Fitch.

FIG. 1.—The rosy aphis: Injury to apple foliage and fruit. (Original.)

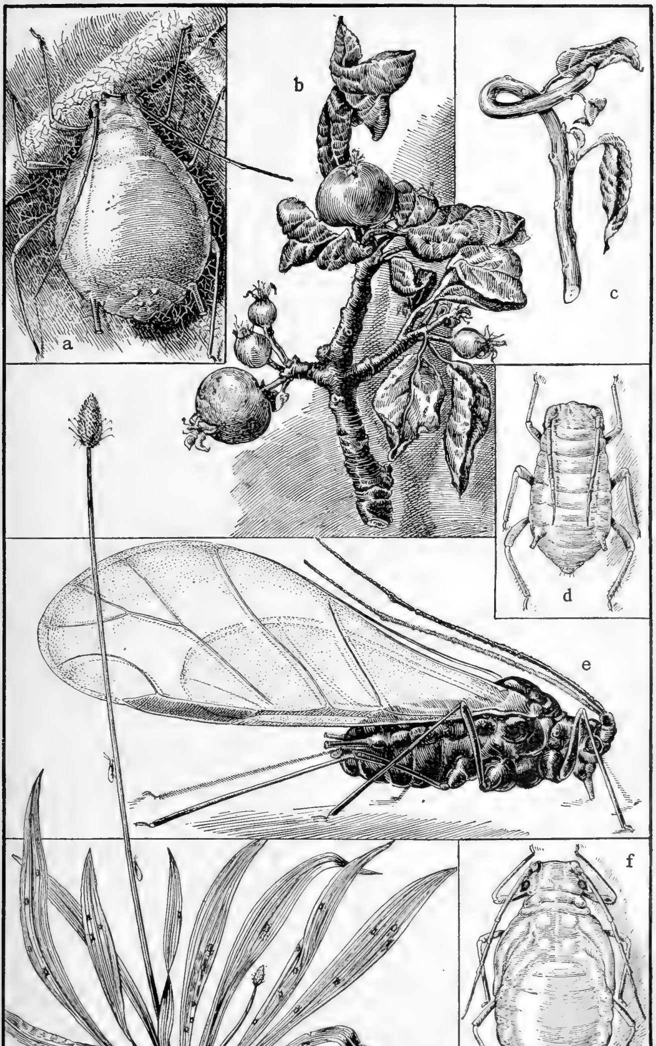

Fig. 2.—The rosy aphis (*Aphis malifoliae*) : *a*, Wingless agamic female ; *b*, injury to fruit and apple foliage ; *c*, injury to apple twig ; *d*, newly born agamic aphid ; *e*, spring migrant ; *f*, pupa of spring migrant ; *g*, rib grass, one of the species of plantain on which the rosy aphis passes the summer. *a, d, e, f*, Greatly enlarged. (Original.)

The rosy apple aphis is easily distinguished from the other forms inhabiting the apple by its color. This varies from light salmon pink to deep purple or grayish black. The young stem-mothers when

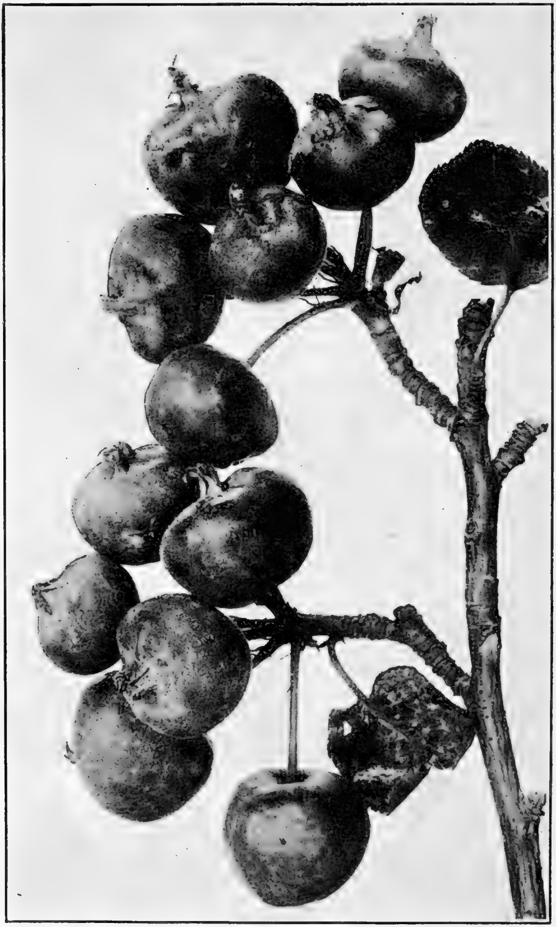

FIG. 3.—The rosy aphis: "Aphis apples." Note that the fruit has failed to thin out in the clusters. (Original.)

first hatched from the eggs are dark green, very similar in color to the young stem-mothers of the green apple aphis. The winged forms (fig. 2, *c*) are dark and often appear almost black, owing to the black head and body and the large black patch upon the abdomen. This is particularly true of the fall migrants, which appear upon the trees in the fall. These produce the orange-yellow, wingless, egg-laying females. The males are winged and similar to the fall migrants. The summer forms occurring upon plantain are yellowish green, with brown patches at the base of the honey tubes.

FIG. 4.—The rosy aphis: Twisted apple twig resulting from injury by this species. (Original.)

SEASONAL HISTORY.

The eggs of this species are deposited on the apple in the fall. They are light yellow when laid and change from green to polished black. They are placed upon the twigs, in the axils of the buds, or in crevices in the bark, but sometimes they are laid upon the larger branches. They begin hatching at about the time the buds are breaking in the spring.

The young stem-mother immediately begins feeding upon the bursting buds, and as the young leaves develop they curl about her.

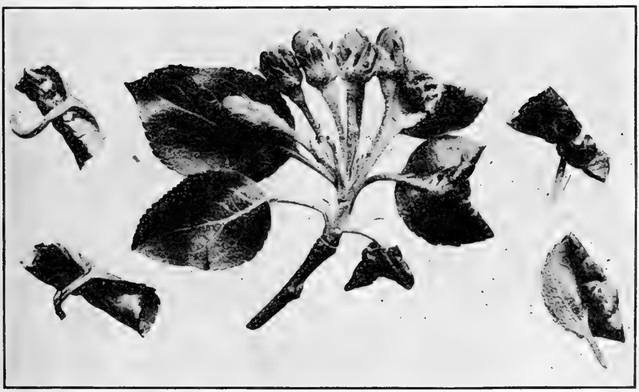

FIG. 5.—The rosy aphis: Condition of the foliage in spring when leaves curled by this insect are first in evidence. (Original.)

(Fig 5.) Usually in 15 days the stem-mother is mature, whereupon she begins producing young (fig. 2, *d*) at an average of 6 a day. The stem-mother lives from a month to six weeks.

The offspring of the stem-mother may either become winged or remain wingless, and this condition may continue for at least 7 generations, so that during these generations both winged and wingless forms are to be found upon the apple. Occasional colonies of wingless forms (fig. 2, *a*) may be found throughout the summer upon the apple. The winged forms, however (fig. 2, *f*, last immature stage, or pupa; fig. 2, *e*, adult) when mature fly to plantains and settle upon the underside of the leaves, or upon the flower stems, where they produce young (fig. 2, *g*). They live principally upon the species known as rib grass, long-leafed plantain, or buckhorn plantain.[1] This migration to the plantains continues, in the vicinity of Washington, from the middle of May until the first part of July. On the plantains the insects continue to reproduce during the summer months. Most of the forms produced on these plants are wingless, although a few winged ones occur throughout the summer. The color of these forms is yellowish green, in contrast to the pink or rosy color of those upon the apple. From 4 to 14 generations of the summer forms occur upon plantain in the vicinity of Washington.

In the middle of September winged forms, consisting of fall migrants (agamic females) and males, begin to appear upon the plantains. These winged forms are able to live and reproduce only upon apple trees or closely related species. The fall migrants leave the plantains and settle upon the underside of the apple leaves, where they produce the young egg-laying females. These egg-laying females are wingless and pale yellowish. The males, which are similar in color to the fall migrants, often being nearly black, fly from the plantains and find the egg-laying females upon the trees. Here mating takes place and the females deposit their eggs about the middle of October. As later females are produced by later migrants, egg-laying continues until freezing weather has killed all the females.

THE GREEN APPLE APHIS.[2]

The green apple aphis lives on the apple throughout the year, and infests the tender terminal growth, causing the leaves to curl, as shown in figure 6, *a*, and figure 7. In young orchards by midsummer the shoots and leaves of the trees may be more or less generally infested, often so much so as decidedly to check the growth. Such trees are likely to be more or less sooty in appearance and overrun with ants. Water sprouts and the shoots of top-worked trees are especially liable to attack. This is the species commonly present on the shoots of apple nursery stock, and much complained of during some years. The work of this aphid is at times confused with that of the apple leafhopper,[3] which distorts the leaves in a manner more or less similar.

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[1] *Plantago lanceolata.* [2] *Aphis pomi* DeGeer. [3] *Empoasca mali* Le Baron.

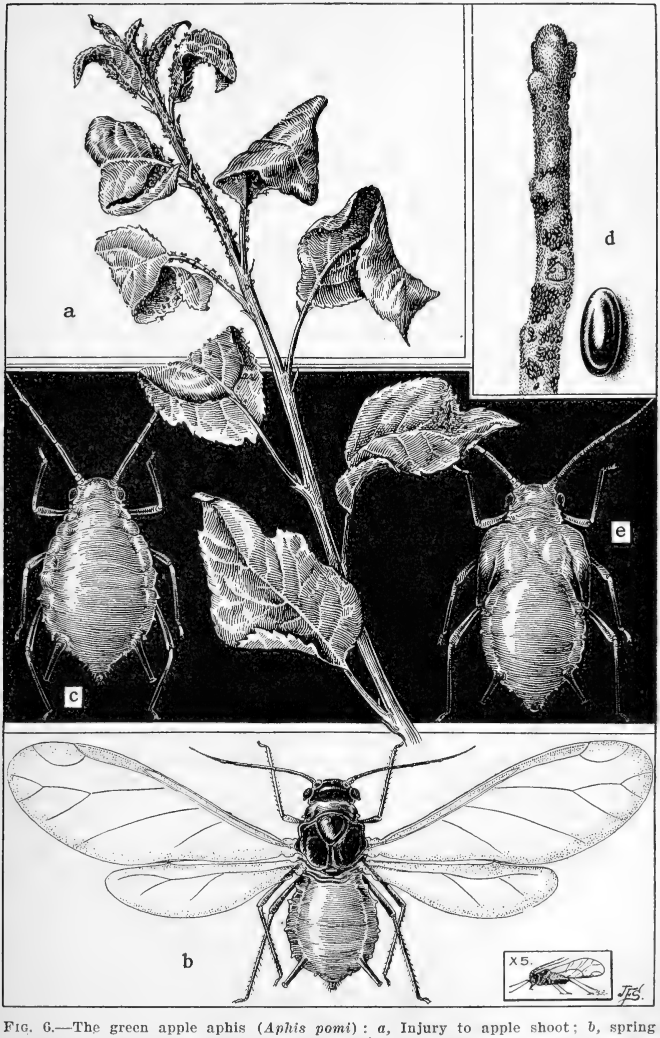

FIG. 6.—The green apple aphis (*Aphis pomi*): *a*, Injury to apple shoot; *b*, spring migrant; *c*, wingless agamic female; *d*, winter eggs on apple shoot; *e*, pupa of spring migrant. *b*, *c*, and *d* (at right), greatly enlarged. (Original.)

The green apple aphis is uniformly green, with black legs, feelers, and honey tubes. Occasionally forms are met which are yellowish, instead of a distinct green. The winged forms (fig. 6, *b*) have a black head and body and a uniformly green abdomen. The males and egg-laying females, which are met during the fall, are somewhat smaller and different in color from the agamic forms (fig. 6, *c*) which occur throughout the summer. The males are orange yellow, sometimes with a brownish tinge, and the females dark green.

Fig. 7.—The green apple aphis: Curled condition of apple foliage due to this insect. (Original.)

SEASONAL HISTORY.

The eggs when first laid are yellowish green, later turning to polished black. They are laid in the fall upon the smooth twigs and water sprouts of the apple (fig. 6, *d*, fig. 8), and seem to be laid rarely on the trunks and larger limbs. A very small percentage of the eggs of this species, sometimes as low as 2 per cent, hatches. Hatching occurs at about the same date in the spring as in the case of the rosy aphis.

The young stem-mothers mature in about 10 days, and in about 24 hours after becoming adult begin to produce living young, reproduction continuing for about two weeks. Between 40 and 50 living young are produced by each stem-mother, at the average rate of 4 a day, although many more may be born daily. Of these young, some develop into winged forms, or migrants (fig. 6, *e*, *b*), and some remain wingless (fig. 6, *c*). They mature in a little over a week, and in turn produce either winged or wingless forms. Occasionally another form, intermediate between the winged and the wingless forms, is met. This reproduction continues throughout the summer, from 9 to 17 summer generations occurring before the sexual forms appear. The true sexes, therefore, appear from the tenth to the nineteenth generation, depending upon the rate of reproduction of their ancestors and upon the time of their birth—that is to say, whether they are early or late young of the parents.

The egg-laying females become adult in from 6 to 16 days, depending upon weather conditions. When adult they mate with the males and begin depositing their eggs upon the apple twigs. Females may be found on the trees until all the leaves have fallen, even when the weather is very cold.

FIG. 8.—The green apple aphis: Winter eggs on apple twig. Much enlarged. (Original.)

THE OAT APHIS.[1]

The oat aphis, sometimes called the European grain aphis, is the earliest apple aphid to hatch in the spring; and as it often occurs in great abundance upon the buds and young foliage, it is frequently the cause of alarm on the part of orchardists. The species probably does not cause important injury, since it migrates from the apple shortly after the blossoms fall.

When first hatched the stem-mothers are very dark green, and they remain this color until after the first molt, when they become much paler. The adult wingless forms are pale green, with rusty areas around the base of the honey tubes, although in the summer some individuals become slightly purplish. The winged forms have black head and body with a green abdomen which is marked with black patches along the sides. The honey tubes, antennæ, and feet are black. The egg-laying females, which occur in the fall, have an olive cast.

SEASONAL HISTORY.

During warm days in winter many of the eggs of this species hatch on the

[1] *Aphis avenae* Fab.

trees, but it is not until about the middle of March, in the vicinity of Washington, that those hatching succeed in escaping destruction and produce stem-mothers. In fact, aphids from eggs hatched before April 1 are sometimes all killed by cold. The important hatching, therefore, commences after April 1.

FIG. 9.—The oat aphis: Young stem-mothers clustered on opening apple bud. Much enlarged. (Original.)

The young stem-mothers of this species usually are abundant upon the swelling apple buds (fig. 9), and when these begin to open the insects crowd down among the bursting leaves. By the time the stem-mothers are adult—usually in about 13 days—many of the buds have opened and the leaves expanded. Each stem-mother produces about 100 young, and these migrate to the underside of the leaves, which become coated with them. These young may become either winged (fig. 11) or wingless adults (fig. 10), and at least four generations may be produced upon the apple. The wingless forms upon apple become mature in about seven days, and each individual produces about 75 young. The period of reproduction lasts a little over two weeks, and the insects live about a month.

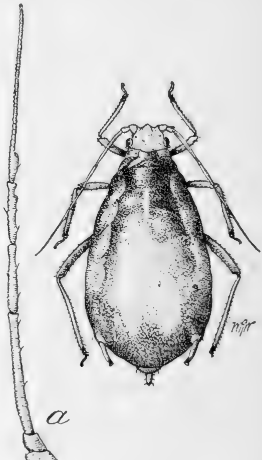

FIG. 10.—The oat aphis (*Aphis avenae*): Wingless agamic female, greatly enlarged. *a*, Antenna of same, still more enlarged. (Davis.)

The winged forms produced upon apples become mature in a little over 8 days and then fly to grains and grasses, as wheat, oats, etc.

In the autumn migrants are produced on grains. These mature in about 2 weeks and return to the apple, the migration lasting 3 or 4 weeks, since not all the migrants are produced in the same gen-

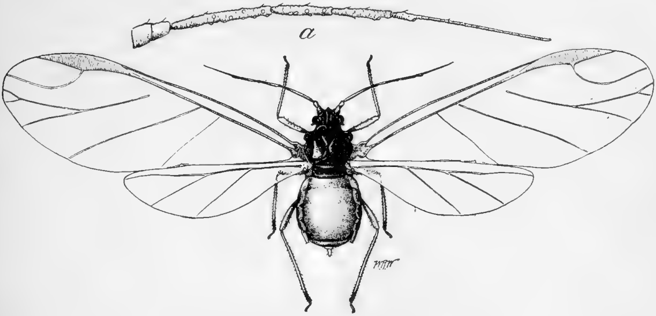

FIG. 11.—The oat aphis: Winged agamic female, greatly enlarged. *a*, Antenna of same, still more enlarged. (Davis.)

eration. During their life of some 6 weeks these migrants produce about 5 egg-laying females each.

The winged males are produced upon the summer food plants and migrate to the apple leaves to mate with the sexual females. After the female has become fertilized she deposits her eggs in crevices of the bark of the larger branches or behind the bud scales of the young twigs of the apple. (Fig. 12.) The length of life of each sex depends upon weather conditions. This is particularly true of the female, which sometimes lives for weeks in a more or less dormant state during cold weather. In warm climates the species may hibernate as wingless females upon the summer hosts.

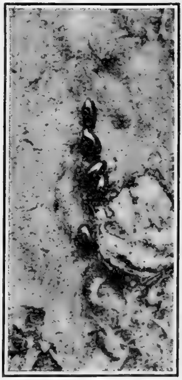

FIG. 12.—The oat aphis: Winter eggs on bark of apple tree. Much enlarged. (Original.)

THE CLOVER APHIS.[1]

The clover aphis, first found injurious to the apple in Colorado, is now known to occur abundantly in some regions in the East. It attacks the apple in a way similar to the green apple aphis, but since there is a considerable migration of individuals to clover, it is less abundant on the apple in summer than the latter species. The stem-mothers of the clover aphis are pink and the individuals of the next generation are yellowish green. The winged forms have a large black patch on the abdomen and in this way resemble the

[1]*Aphis bakeri* Cowan.

migrants of the rosy aphis. The two species, however, can be distinguished readily by the length of the honey tubes. In the rosy aphis these are very long, while in the clover aphis they are short. The forms of this species which live on clover are pink.

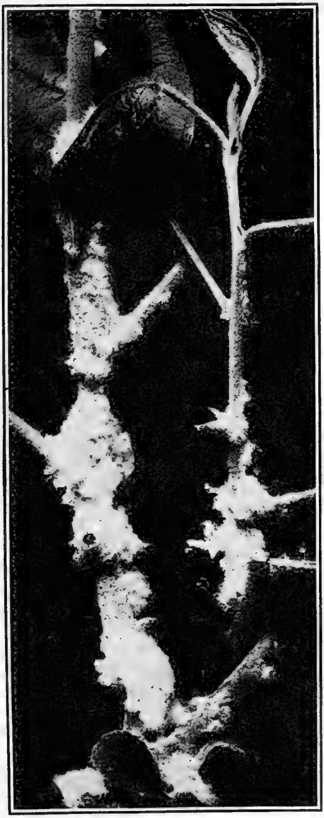

FIG. 13.—The woolly apple aphis (*Eriosoma lanigerum*): Colonies on apple shoots. (Original.)

SEASONAL HISTORY.

The eggs of the clover aphis are laid upon the apple in much the same manner as those of the species already mentioned. The stem-mothers, which are hatched considerably earlier than those of the rosy aphis and the green apple aphis, give birth to winged and wingless forms, which in turn produce young, some of which become winged, while the others remain wingless. As a rule most of the insects have become winged by early summer, although some wingless colonies occur during the summer on apple. These winged forms fly to clovers, and settling upon the stems produce wingless young. These and succeeding generations, which may contain winged individuals, pass down to the crown of the clover plants, and here the species lives throughout the summer. During October numerous fall migrants are produced upon the clovers and fly to the apple, where they give birth to the young egg-laying females. Winged males produced upon the clovers follow the fall migrants to the apple, and here mate with the females, which later deposit their eggs.

THE WOOLLY APPLE APHIS.[1]

The woolly apple aphis is often in evidence in summer on the trunk, branches, and twigs of the apple as bluish white cottony patches (fig. 13) which hide the rusty or purplish brown aphids beneath.

[1] *Eriosoma lanigerum* (Hausm.)

While principally injurious to the roots of the apple, its injuries above ground are at times quite important. In orchards grown under arid or semiarid conditions in the West it is decidedly more troublesome than in the East, attacking the tree wherever the bark is tender and sometimes infesting the stems of the leaves and fruit. Its injuries above ground often result in galls or swellings similar to those on the roots, and when the fruit spurs are invaded (fig. 14) the fruiting capacity of the tree may be interfered with seriously. The usual contact sprays will be effective in destroying this pest on the limbs and branches. Its treatment on the roots of the apple requires essentially different methods, which are not considered in this bulletin.

FIG. 14.—The woolly apple aphis: Injury to fruit spurs of apple. (Original.)

APPLE APHIDS OF MINOR IMPORTANCE.

Several additional species of aphids are found upon the apple, but these are at present of minor economic importance.

The potato aphis[1] has been found feeding upon apples occasionally in the spring. Its normal winter host appears to be the rose. This form is very much larger than the others mentioned, and the winged forms, as well as the wingless one, is uniformly light greenish.

Another species, which is slaty blue or black, with white bands upon the legs, and often possesses white waxy tufts, occurs sometimes upon the apple. This is the dock aphis.[2] The apple does not seem to furnish suitable food to these insects, for after a few generations they always leave the trees.

[1] *Macrosiphum solanifoliae* (Ashm.). [2] *Aphis rumicis* L.

A second dark brown or blackish species which occurs occasionally upon apples is the bur-clover aphis.[1] It is sometimes met during the spring upon apple foliage.

Still another species, the wild-carrot aphis,[2] occurs commonly on the apple in the fall, particularly as the winged form. Its summer hosts are the wild carrot and related plants, and the winged forms fly to honeysuckles, but occasionally select apples.

The thorn-leaf aphis[3] also is found occasionally upon apple. Its life history is discussed under aphids attacking the quince.

QUINCE APHIDS.

Two species of aphids which have been discussed under apple occur commonly also upon quince foliage—namely, the green apple aphis and the oat aphis. Their life histories are similar on quince and apple, and the same remedial measures apply.

THE THORN-LEAF APHIS.

The thorn-leaf aphis,[3] called also the long-beaked clover aphis, is most common upon hawthorn trees. Although first found upon thorn, it is not uncommon upon quince leaves. It resembles very closely the clover aphis as found upon apple, but can be distinguished from that insect by its long beak.

On thorn trees the feeding of this species results in a curling of the leaves which is very conspicuous, the twisted leaves taking on a purplish cast. On quinces, however, it does not curl the leaves, or at least not to such an extent.

SEASONAL HISTORY.

The eggs of this insect are laid in the fall upon the twigs of the quince, and the stem-mothers hatch in the early spring. By early summer the insects are abundant and winged forms are being produced. This production of winged forms, or migrants, continues until late summer. The migrants fly from their winter hosts to clovers and peas and produce numerous generations on these plants in a manner very similar to that of the clover aphis. In the fall, migrants are produced which return to the quinces and produce the egg-laying females, which after mating with the males deposit the winter eggs. The flight of the insects from clover begins in September and extends throughout October.

PEAR APHIDS ATTACKING THE FOLIAGE.

Several species of aphids are found upon pear foliage. Most of these, however, occur also upon other trees and are treated elsewhere

[1] *Aphis medicaginis* Koch.
[2] *Hyadaphis xylostei* (Schrank).
[3] *Aphis crataegifoliae* Fitch.

in this bulletin. The more common forms upon pear are the green apple aphis, the oat aphis, and the clover aphis.

Another species, the woolly thorn aphis[1] is common in some localities. Both winged and wingless forms are covered with a white waxy substance. The wingless forms are pale green and the winged forms have a black head and body. The insects hatch in the early spring and soon attack the leaves, curling and twisting them. During early summer the winged forms leave the pear tree. In the fall migrants may be found again, and these produce the sexual forms, the females of which lay their eggs upon the bark. Besides pear, this species occurs upon thorn, quince, and Juneberry.

Two other forms are found commonly upon pear, but these occur upon the roots, and since they are seldom found upon the branches and foliage and require different remedial measures, they are not treated in this bulletin. The first of these is the woolly pear aphis,[2] which is common in the western part of the country, and the second is Fitch's pear root aphis,[3] which is very similar to the woolly thorn aphis and occurs in the eastern United States.

PLUM APHIDS.

Three or four species of aphids are common on the plum, two of which are, during some seasons, very injurious. Many complaints of injury to Japanese and native plums by the rusty plum aphis have come from the more southern States, while the mealy plum aphis is more often prevalent in the North and West, on Domestica, or the European type of plums. The hop aphis, according to records of the Bureau of Entomology, has not occasioned much injury to plums in recent years, although in the Pacific Northwest it continues to be a pest of importance to hops.

THE RUSTY PLUM APHIS.[4]

The rusty plum aphis was discovered and named from individuals feeding on grass, but is better known by its injuries to plums. It is rusty brown or deep purplish, with white bands upon the legs.

This species feeds upon the tender twigs and foliage of the plum and also upon the peach. The first stem-mothers attack the buds just as they are expanding in the spring and later crawl down among the opening leaves. As the season advances whole twigs or small branches may be literally crowded with the aphids (fig. 15), and such twigs usually die. Another species, not yet named, also has this habit, and this form may be very injurious to the twigs, as it remains on the plum throughout the summer.

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[1] *Prociphilus corrugatans* (Sirrine).
[2] *Eriosoma pyricola* B. & D.
[3] *Prociphilus pyri* (Fitch).
[4] *Aphis setariae* Thos.

SEASONAL HISTORY.

The eggs of the rusty plum aphis hatch early in the spring and the normal life period of the stem-mother is about a month. During this time she produces young at the rate of four to six a day. In a little over a week these young are mature and reproducing, so that large colonies soon result. A few winged forms occur in the early generations, but it is not until late spring that a large percentage of spring migrants is found. These winged forms fly from the plum and settle upon various grasses, where they produce colonies throughout the summer around the crowns of the plants. In October the fall migrants are produced upon the grasses, return to the plum, and there give birth to the egg-laying wingless females. The males, also produced upon the grasses, migrate to the plum in order to locate and fertilize the egg-laying females. In some regions the species seemingly lives on the plum throughout the year.

Fig. 15.—The rusty plum aphis (*Aphis setariae*): Colony on shoot and foliage of plum. (Original.)

THE LONG-BEAKED THISTLE APHIS.[1]

In some localities the long-beaked thistle aphis is abundant on plum trees. In structure this species most closely resembles the rusty plum aphis. The insects are shiny green and black, some of the wingless ones and all of the winged ones having a large black patch on the abdomen.

Although this species becomes very abundant on the trees, it does not curl the leaves to any extent. Trees have been observed in the vicinity of Washington with the underside of nearly every leaf thickly covered with the insects, and yet these leaves were rolled only slightly from the edges. The insects always feed on the underside

[1] *Aphis cardui* L.

of the leaves or on the very tender twigs. Practically all the injury done to the trees is by the spring forms, the fall migrants being scattered.

SEASONAL HISTORY.

The eggs of this species are laid upon the plum, as are those of the rusty plum aphis. In the early spring the stem-mother hatches and gives birth to living young. Winged forms begin to appear as early as the second generation and continue to be produced until midsummer. These migrate to thistles, where they produce the first of the summer forms. After having produced numerous generations on the thistle during the summer, fall migrants are produced which return to the plum trees to deposit the young egg-laying females. These, after being fertilized by the males, lay the winter eggs.

THE WATER-LILY APHIS.[1]

Plum trees are sometimes thickly infested by an aphid with swollen honey tubes, the water-lily aphis. The insects are brownish, the winged forms having a black head and body.

The spring forms feed upon the underside of the leaves or on the tender twigs of the plums, but they do not curl the leaves to any extent. The summer feeding habits of the species on water plants are very interesting, as colonies often are partially submerged for some time without apparent injury.

SEASONAL HISTORY.

The stem-mothers of this species hatch early in the spring upon the plum, and soon the young produced cover the lower side of the leaves and the twigs. Winged forms are found during June and these fly to various water plants, on which they reproduce and live during the summer months. In the fall the migrants return to the plum and produce the egg-laying females, which, when adult, are fertilized by the winged males. The flight of the fall migrants and males extends over a long period, the males having been found on the plum trees from early until late fall.

THE HOP APHIS.[2]

A large green aphid, the hop aphis, is in some regions very common upon plums in the spring. The wingless forms are light green and the winged forms are light green with black head and body and a patch of the same color on the abdomen.

The stem-mothers of this species feed upon both the flower buds and the leaf buds of the plum. After the leaves have expanded the insects attack the underside of the leaves and often may be found thickly crowded thereon.

[1] *Siphocoryne nymphaeae* (L.).

[2] *Phorodon humuli* (Schrank.

SEASONAL HISTORY.

The eggs hatch on the plum twigs considerably later as a rule than those of the thistle aphis. The young stem-mothers soon develop and begin the production of young. Winged forms soon appear, the greater number of these occurring in the third generation. These winged forms fly to hop vines, where they produce young that feed upon the hop plant. Eight or more generations of these summer forms are produced upon the hop, and winged fall migrants are then produced, which return to the plum trees to produce the sexual females. Males appear during the fall for a period of several weeks, the last ones usually occurring late in October or in November. These fertilize the egg-laying females, which then lay their eggs upon the twigs.

In some cases the species is able to complete its life cycle on the hop and does not necessarily alternate with the plum, whereas in other cases it remains all summer upon the plums.

THE MEALY PLUM APHIS.[1]

The mealy plum aphis is a common form on plum trees and it can be distinguished from the other species attacking plum foliage by its uniform green color and the fine, white, powdery covering of the body. The honey tubes also differ in that they are very short.

These insects feed upon the underside of the leaves, often being very closely packed together. (Fig. 16.) As a rule they do not curl the leaves, even when present in great numbers.

SEASONAL HISTORY.

The stem-mothers of this species hatch from the winter eggs on the plum early in the spring and in about 10 days they are mature. They then give birth to young, and these when grown produce others until the leaves are often thickly covered with the insects. Winged forms develop toward late spring and continue to appear until late midsummer or later. These winged forms migrate to certain grasses and produce numerous generations during the summer. In the fall return migrants are produced, which give birth to the egg-laying forms on the plums. These migrants first appear in early September, but continue to arrive until late October or early November.

CHERRY APHIDS.

THE BLACK CHERRY APHIS.[2]

The black cherry aphis is an abundant species almost everywhere upon cherry trees. The wingless insects have a rounded abdomen, which gives them a more or less globular appearance. Both wing-

[1] *Hyalopterus arundinis* (Fab.). [2] *Myzus cerasi* (Fab.).

less and winged forms are shining deep brown to black, while the color of the young ranges from amber through various shades of brown. The young stem-mothers are deep greenish.

On account of their early hatching in spring the young stem-mothers do not find leaf food available. They therefore attack

FIG. 16.—The mealy plum aphis (*Hyalopterus arundinis*) : Infested plum foliage. (Original.)

the buds even before these show any signs of bursting. Sometimes the stem-mothers will feed in this manner for nearly a week before the buds begin to open. As soon as the leaves are formed the young insects attack them and cause them to curl. As they spread from leaf to leaf a large and conspicuous cluster of curled-up leaves (fig 17) is formed, within which the insects feed.

SEASONAL HISTORY.

The eggs are laid upon the cherry twigs in the fall and hatch early in the spring. The insects are able to withstand freezing weather, and after the return of warmer weather continue their activities. Within two or three weeks after hatching the stem-mothers are mature and produce young. These later generations become adult usually in less than a week. Some of the insects so produced become winged while others remain wingless. The winged ones migrate to some plant not known, and here the species lives throughout the summer. The wingless ones continue reproduction, and sometimes give rise to as many as 11 generations before the end of July. The numbers on cherry, however, gradually diminish, and during midsummer very few are seen upon the trees, and in some cases no insects can be found upon trees which earlier in the season were badly infested. During October fall migrants and winged males may be found returning to cherry trees and are often encountered during the migration period in larger numbers than might be expected. The fall migrants produce the egg-laying females which, when mature, are fertilized by the males.

FIG. 17.—The black cherry aphis (*Myzus cerasi*): Curled terminal cherry leaves following attack by this species. (Original.)

THE CHOKECHERRY APHIS.[1]

The chokecherry aphis is found abundantly upon chokecherries and related trees. It is a pale green insect and is conspicuously mealy. The winged forms have a black head and body.

The feeding habits of this species are very similar to those of the black cherry aphis. The leaves of the terminal twigs are attacked and twisted by the feeding of the insects, entire twigs sometimes being destroyed.

As in the case of the black cherry aphis, the eggs of this insect are laid on the cherry twigs. After the stem-mothers have become mature and produced young, these latter crowd the terminal leaves. Winged forms are produced during early summer, and by midsummer the insects usually have disappeared from the trees. Their summer host is not known, but in the fall migrants return to the cherry trees to deposit the egg-laying females.

PEACH APHIDS.

THE GREEN PEACH APHIS.[2]

The green peach aphis is a common form upon peach trees. The stem-mothers in spring, as well as the fall egg-laying females, are

FIG. 18.—The green peach aphis (*Rhopalosiphum persicae*): Colony on underside of peach leaves. Much enlarged. (Original.)

often pinkish, and at other times light green. The wingless agamic form also is light green, while the winged individuals have a black head and body and a large dark-brown patch on the abdomen. This marking occurs upon both the spring migrant and the fall migrant. They are similar in other respects excepting that the fall form has the honey tubes somewhat swollen.

On the peach this species feeds entirely upon the leaves, on which the insects may be found in large numbers crowded on the underside. (Fig. 18.) It has a large number of other food plants, including numerous garden vegetables.

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[1] *Aphis cerasifoliae* Fitch. [2] *Rhopalosiphum persicae* (Sulz.).

SEASONAL HISTORY.

The eggs of this aphid are laid upon the peach twigs, and early in the spring before the buds are opened the green stem-mothers are hatched. From this form during the spring may be produced one or more generations of wingless individuals upon the leaves. Spring migrants, however, begin to occur very early and continue to appear until the middle of June. These fly to a large number of different plants, where numerous generations occur throughout the summer. During September and October fall migrants are developed which return to the peach, where they deposit the young egg-laying females. These are fertilized by the winged males, which also have returned to the peach, and the females then lay their eggs upon the twigs. Occasionally, however, migrants are found which do not return to the peach and these deposit egg-laying females upon the summer host plants.

Fig. 19.—The black peach aphis (*Aphis persicae-niger*): Colonies on peach shoot in early spring. (Original.)

THE BLACK PEACH APHIS.[1]

The well-known black peach aphis is injurious to the twigs, shoots, and roots. It is shiny dark brown to black, with the young an amber color.

The insect lives throughout the year on the roots of the peach and is most injurious to peach growing on sandy soils. It is prevalent in portions of Maryland and in Delaware, New Jersey, and Michigan. Individuals migrate from the roots during the warm periods in winter or in early spring and start colonies on the twigs and young shoots. (Fig. 19.) Often these become so numerous as to cause the

[1] *Aphis persicae-niger* Smith.

death of dormant-budded nursery trees (fig. 20) and do serious or fatal injury to young orchard trees. In mild climates the insects may exist all winter on the twigs, reproducing during periods of warmth, though the twigs are for the most part reinfested each year from the insects below the soil.

The complaints of serious injury by this species on the roots of orchard peach trees, in the experience of the writers, have not been justified, the unthrifty condition of the trees being in most cases due to other causes.

FIG. 20.—The black peach aphis: Injury to dormant-budded peach nursery stock in the spring. (Original.)

SEASONAL HISTORY.

The complete seasonal history of this species is not known. The number of young produced by a given parent varies greatly, depending upon weather conditions. Sometimes only one young aphis a day will be produced, with a total of 25 or 30 young to a mother, while under favorable conditions as many as 12 young may be produced in a day and considerably over 100 as the total for a given parent. In spring large numbers of winged forms appear and the percentage of these gradually increases until all of the forms above ground have become winged. These fly to some plant or plants not known and are not met on peach foliage until the next year.

CURRANT AND GOOSEBERRY APHIDS.

THE CURRANT APHIS.[1]

The currant aphis is distributed over the entire country and its injury, on account of its conspicuousness, is the occasion of much complaint. The insect causes the terminal leaves to become much

[1] *Myzus ribis* (L.).

distorted, and little pits or pockets are formed on the underside. (See fig. 21, *b*; fig. 22.) The upper surface of the leaves assumes a more or less reddish color, evident some distance away. When the plants are badly infested these leaves fall and the fruit becomes poor and ripens prematurely. Red currants are most subject to attack, but black currants and gooseberries also are injured.

The stem-mothers of the species are green, the other wingless forms (fig. 21, *a*) a yellowish green, while the winged ones have a black head and body and a large black patch on the abdomen. The eggs are polished black.

SEASONAL HISTORY.

The stem-mothers hatch from the eggs in the early spring soon after the leaves open. After completing their growth they produce young aphids which infest the lower surface of the leaves. Some of the offspring of the stem-mother are winged and these fly to some unknown host. The wingless ones remain upon the currants and continue reproduction. In each generation some winged forms occur, but wingless individuals are present until late in July upon the currants. In fact, occasional colonies remain throughout the summer. In the fall, during early October, migrants return to the currant bushes and deposit the sexual females. These when mature are fertilized by the winged males and the eggs are laid upon the twigs.

THE SOW-THISTLE APHIS.[1]

The sow-thistle aphis is at times quite as abundant on currants as is the currant aphis. It is somewhat similar in color but can be distinguished at once from the currant aphis by the swollen honey tubes. (Fig. 21, *c*.) In the currant aphis these are long and very slender. (Fig. 21, *a*.) The eggs are polished black. The sow-thistle aphis injures the currant in about the same way as does the currant aphis, though the infested leaves (fig. 21, *d*) do not take on a reddish coloration.

SEASONAL HISTORY.

The seasonal history of this species upon currants is very similar to that of the currant aphis. The winged forms, however, migrate to the sow thistle and upon this they reproduce. After the production of numerous generations here during the summer, fall migrants are developed which return to the currants. Egg-laying females are then produced and these are fertilized by the winged males. The eggs are laid upon the twigs at about the same time as those of the currant aphis.

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[1] *Rhopalosiphum lactucae* (Kalt.).

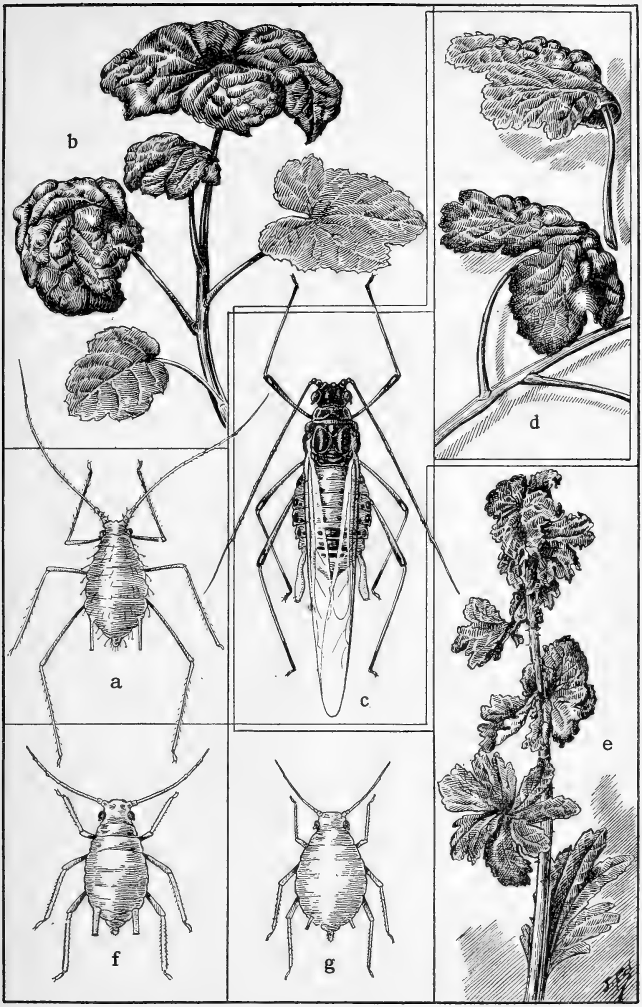

FIG. 21.—Currant aphids: *a,* Wingless agamic female of the currant aphis (*Myzus ribis*); *b,* distorted currant foliage due to attack of this species; *c,* spring migrant of the sow-thistle aphis (*Rhopalosiphum lactucae*); *d,* injury to currant by this species; *e,* work of the green gooseberry aphis (*Aphis sanborni*) on gooseberry; *f,* wingless agamic female of the New Mexico gooseberry aphis (*Aphis neomexicanus*); *g,* wingless agamic female of Sanborn's currant aphis (*Aphis ribis*). *a, c, f, g,* Greatly enlarged. (Original.)

THE GREEN CURRANT APHIS.[1]

A species which may be called the green currant aphis has for years been confused with the currant aphis, which it resembles closely. The wingless forms of the present species are green, whereas those of the currant aphis are yellowish. The life history, so far as is known, is very like that of the currant aphis and the two forms often may be found on the same leaf.

FIG. 22.—The currant aphis: Injury to currant foliage. (Original.)

THE VARIABLE CURRANT APHIS.[2]

The variable currant aphis is one of the most injurious species. The stem-mother is purplish green with white honey tubes. The wingless form is dark green, tan, or dark brown, whereas the winged form has a black head and body, with a dark green abdomen marked near the tip and on the sides with black.

As soon as the stem-mother begins to feed, the young leaf begins curling about her. As young are produced other leaves are attacked

[1] *Myzus dispar* Patch. [2] *Aphis varians* Patch.

until large irregular bunches of twisted leaves occur. Later the insects attack the shoots, sometimes thickly covering them. The species infests currants, gooseberries, and flowering currants.

SEASONAL HISTORY.

The stem-mother hatches from the eggs early in the spring and becomes mature early in May. She produces young which are all wingless. These in turn produce young which may or may not be winged. The winged ones take flight to some unknown summer host, while the wingless ones continue the infestation upon the currants until nearly midsummer. In the fall migrants return to the currants and produce young which develop into males and egg-laying females, the latter depositing eggs upon the twigs.

THE GREEN GOOSEBERRY APHIS.[1]

The green gooseberry aphis is a green species with white honey tubes. It lives upon the underside of gooseberry leaves, which it deforms badly (fig. 21, *e*), and also upon the twigs.

The seasonal history of this species has not been determined. The winter eggs are laid upon the host plant upon which the stem-mother develops. Wingless forms occur later than the stem-mother, and winged ones also are produced upon the gooseberry.

THE HOUGHTON GOOSEBERRY APHIS.[2]

A pale green species is sometimes found curling the leaves of Houghton gooseberries. The winged forms are somewhat darker than the wingless ones. The life history of the species is unknown.

THE NEW MEXICO GOOSEBERRY APHIS.[3]

Another species is found on gooseberries in New Mexico. The wingless forms (fig. 21, *f*) are green, while the winged forms have black head and body, with green abdomen marked with some dark bands or spots. Its life history is unknown. A variety of this species is found in California, feeding upon the red currant.

SANBORN'S CURRANT APHIS.[4]

A small species of aphid occurs in the Middle West and Southwest on Missouri gooseberries and cultivated currants. This is Sanborn's currant aphis. The wingless forms (fig. 21, *g*) are green, and the winged forms have black head, body, legs, honey tubes, and antennæ. The species is found in the spring in rather large colonies on the underside of the leaves, which it causes to curl and twist.

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[1] *Aphis sanborni* Patch.
[2] *Aphis houghtonensis* Troop.
[3] *Aphis neomexicanus* (Ckll.).
[4] *Aphis ribis* Sanborn.

GRAPE APHIDS ATTACKING THE FOLIAGE.

The well-known grape phylloxera occurs in some localities upon grape foliage (fig. 23), but this species is not treated in this bulletin,

FIG. 23.—Galls of grape phylloxera (*Phylloxera vitifoliae*) on grape leaf. (Original.)

since it is injurious principally to the roots and requires control measures radically different from those employed against foliage-inhabiting species.

THE GRAPEVINE APHIS.[1]

The grapevine aphis is very numerous in some localities, infesting the tender shoots and leaves (fig. 24) and sometimes the fruit clusters, causing the berries to drop. It can be distinguished easily from any other forms occurring upon grape by its large size and its dark-brown color.

FIG. 24.—The grapevine aphis (*Macrosiphum illinoiensis*): Colony on grape shoot. (Original.)

SEASONAL HISTORY.

The eggs of this species are laid upon the twigs of the black haw (*Viburnum prunifolium*). Very early in the spring they begin hatching, but these first stem-mothers may be killed by frost. Six or eight weeks later the aphids of the second generation mature, and these nearly all become winged. These migrants fly to the grape and produce young upon the tender growing shoots, where in less than 10 days they are mature and producing young. Reproduction on the grape continues throughout the summer, and often more than a dozen generations may occur. In each generation winged forms are found, and these carry the infestation to new vines. During October fall migrants are produced, which return to the haw trees and deposit the egg-laying females. When mature these are fertilized by the winged males which follow the fall migrants, and egg laying follows.

NATURAL ENEMIES OF APHIDS.

Aphids are attacked by various species of parasitic and predacious insects and by fungous diseases, and these agencies exert a very im-

[1] *Macrosiphum illinoiensis* (Shimer).

portant influence in their control. The combined effect of these several factors normally keeps the aphids pretty well reduced, but when for any reason their activities are lessened the aphids may increase enormously and do widespread injury. Heavy driving rains are believed to be inimical to aphids, whereas cool, cloudy weather seems to reduce the activities of the parasitic and predacious enemies, permitting the aphids to become correspondingly abundant.

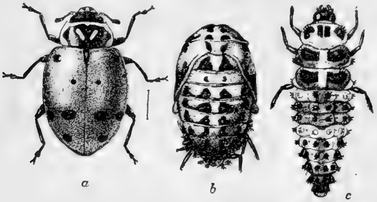

Fig. 25.—The convergent ladybird (*Hippodamia convergens*), an enemy of orchard aphids: *a*, Adult; *b*, pupa; *c*, larva. Enlarged. (Chittenden.)

Ladybird beetles (fig. 25) may be found in almost any colony of aphids, both the beetles and larvæ feeding freely on the insects. Numerous species of these beetles attack the aphids, and they should be protected and encouraged when possible.

Larvæ, or maggots, of syrphus flies, also called sweat flies (figs. 26 and 27), are very generally present in aphid colonies and are most important checks to their increase.

The larvæ of two or three species of lacewing flies feed freely on aphids, although they are not so important as the insects mentioned above.

Probably the most important check to aphid increase, however, is the work of certain minute, four-winged flies which live parasitically on the aphids. These multiply very rapidly and under normal conditions are very effective. The bodies of parasitized aphids usually become enlarged, assume a more or less globular shape, and finally show the exit hole of the adult parasite. (Fig. 28.)

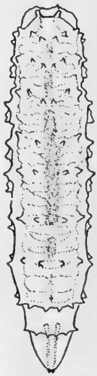
Fig. 26.—Larva of the syrphid fly *Allograpta obliqua*, an important enemy of aphids. Much enlarged. (Metcalf.)

CONTROL MEASURES.

As previously stated, aphids feed upon plant juices which they obtain by means of a beak inserted into the plant tissues. Paris green, arsenate of lead, and other arsenicals, or stomach poisons, are therefore ineffective against these insects, and the so-called contact sprays, such as kerosene emulsion, soap washes, nicotine sprays, etc., must be employed. These sprays, to be effective, must come in contact with the bodies of the insects, and great thoroughness in spraying is necessary.

Two principal plans of attack may be followed in the control of orchard aphids. Those species which winter in the egg stage on the plants to be protected may be treated with sprays early in the spring as the buds are expanding, to destroy the young stem-mothers. Treatment at this time assumes that without it the aphids would become injurious later in the season and is in the nature of insurance.

Following the other plan, spraying is not done until the insects actually have become troublesome, which does not occur as a rule until several weeks after the foliage has put out. With species that cause the leaves to curl this is too late to obtain much benefit from spraying. In view of the more or less scattered occurrence of aphids many growers will prefer to delay treatment until the insects actually are present on the plants in destructive numbers, and in the case of those species which do not curl the leaves to any extent this plan will

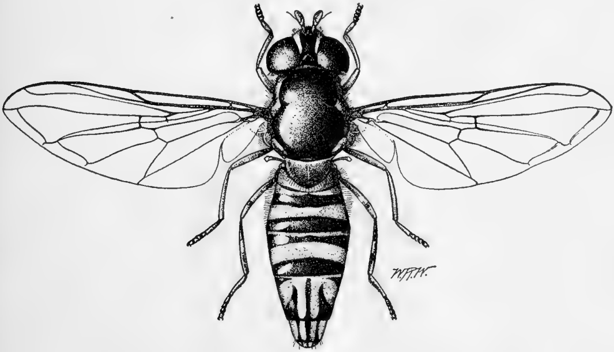

FIG. 27.—The adult syrphid fly *Allograpta obliqua*. Much enlarged. (Davis.)

be satisfactory. It is a question for the grower to decide whether under his conditions danger of aphid injury, especially by the leaf-curling species, makes the bud application desirable or whether this danger is so small that he is warranted in taking chances on the insects becoming troublesome. Examinations of the plants to determine the abundance of winter eggs and young stem-mothers on the opening buds should be of assistance in this connection.

SPRAY FORMULAS.

COMMERCIAL NICOTINE SOLUTIONS.

Aphids are killed by surprisingly small quantities of nicotine in water, and because of the entire safety with which it may be applied to plants nicotine is better suited than other sprays to control these insects. While the cost of the concentrated article is high, the ex-

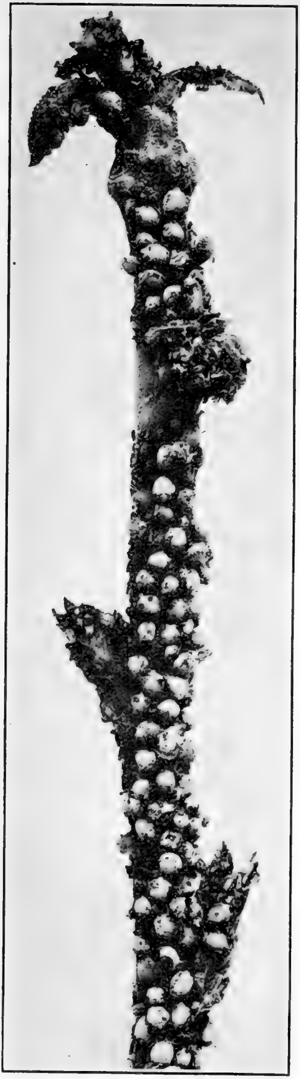

FIG. 28.—A colony of the black peach aphis on peach twig heavily infested by a species of parasitic four-winged fly. Enlarged. (Original.)

tent to which it may be diluted makes the spray compare favorably in cost with other contact sprays. Nicotine is extracted from refuse tobacco, principally stems, by different commercial concerns, and is put on the market in several grades and strengths. The 40 per cent nicotine sulphate is the solution principally used, although weaker grades of nicotine may be employed provided care is taken that the spray be made so as to contain not less than 0.05 or 0.06 per cent of actual nicotine.

Nicotine may be added either to the winter-strength lime-sulphur solution for the San Jose scale or to the dilute lime-sulphur solution and arsenate of lead spray employed in the control of insects and diseases of fruit and foliage. It may also be used in Bordeaux mixture and arsenate of lead spray without interfering with its effectiveness or in an arsenate of lead, milk of lime, and water spray. In orchard spraying the 40 per cent nicotine sulphate is used at the rate of about three-fourths of a pint to 100 gallons of water, lime-sulphur solution, or Bordeaux mixture. When used in water the addition of soap at the rate of 4 or 5 pounds to 100 gallons adds much to its spreading power and efficiency. Soap should not be used with lime-sulphur solution, but may be used in Bordeaux mixture. Where only a small quantity of spray is required the nicotine sulphate may be used at the rate of 1 teaspoonful to a gallon, or 1 ounce to 8 gallons of soapy water.

HOMEMADE NICOTINE SPRAYS.

Where tobacco stems or refuse tobacco are available it is practicable to make nicotine sprays at home. Owing to the variation in nicotine content of tobacco refuse, there is danger of having the spray too weak on the one hand or stronger than necessary on the other.

The following table, adapted from Bulletin 208 of the Virginia Agricultural Experiment Station, illustrates the variation in nicotine content of tobacco stems, refuse, and various kinds of tobacco, and may serve as a guide to those planning to make decoctions from tobacco refuse at home:

Formula for making nicotine extracts.

Lab. No.	Kind of tobacco.	Where from.	Nicotine.	Number of pounds per 100 gallons necesary to make solutions containing different percentages of nicotine.	
			Per cent.	*0.06 p. ct.*	*0.05 p. ct.*
1	Light stems	Richmond, Va	0.481	145	121
2	.....do	Danville, Va	.609	110	91
3	Sweepings	.....do	.884	74	62
4	N. L. Orinoco	Appomattox, Va	5.535	12¼	10⅓
5	Olive	Powhatan, Va	3.367	19½	16¼
6	Light	Danville, Va	2.984	22	18
7	Sweepings	Louisville, Ky	.753	91	85
8	Smoker	Chatham, Va	2.306	28¼	23½
9	Wrapper	.....do	3.05	21½	18
10	Cutter	.....do	3.466	19	15
11	Dark	Appomattox, Va	2.835	23¼	19¼
12	N. L. Orinoco	Bowling Green, Va	5.629	11¾	10
13	Medium smoker	Chatham, Va	3.766	17½	14½
14	Common smoker	.....do	2.47	26	21½

Tobacco decoctions can be made conveniently in a lime-sulphur cooking plant, being heated either by steam or by fire under open kettles. The proper quantities of refuse tobacco and water should be placed in the container and the water heated to about the boiling point, after which it should be allowed to cool. Where steam is used a slight increase in water will occur, and a slight decrease where fire is used, although the variation usually will be negligible. Heating the decoction by either method may result in a slight loss of nicotine, especially if the water is allowed actually to boil.

Another method is simply to soak the tobacco refuse in water for 24 hours with frequent stirrings, using a barrel, vat, or other suitable container. This method removes about the same amount of nicotine (70 to 80 per cent) as does the heating process. After the heating or soaking has been completed the decoction should be strained to remove fragments of leaves, etc., and if pressure can be applied to the mass of refuse some additional liquid will be obtained.

Reference to the table will indicate the amounts of several types of refuse which should be used to produce an effective aphid spray. Probably in most cases the refuse at hand can be considered as belonging to some one of the types indicated in the table. Observations as to the effectiveness of the spray should be made, however, so that it may be strengthened if needed.

In this connection it should be remembered that the stems from which the extract has been made have a value for fertilizer purposes of about $10 per ton. With tobacco refuse and stems costing about $20 per ton, the spray solution will cost approximately 1 cent per gallon, the fertilizer value of the extracted refuse covering the cost of labor, etc., in the preparation of the spray.

Tobacco sprays should be made up as needed, since after a day or so fermentation begins.

SOAP WASHES.

Washes made of fish-oil[1] or laundry soap are effective against aphids, and are especially suitable for use on a small scale where only a few plants are to be treated, although fish-oil soap washes are used by many orchardists in the treatment of aphids, the pear Psylla, etc., and compare favorably in cost and effectiveness with nicotine and kerosene emulsion sprays. Both potash and soda fish-oil soaps are on the market. Potash soap is softer and hence there is less trouble in dissolving it in water. Soda soap usually must be sliced and dissolved in hot water before use.

Fish-oil soap of different brands varies greatly in water content, so it is not possible to indicate the precise quantity of soap to be used with a given amount of water for all brands of soap. However, since a statement, on the label, of the amount of the active ingredients (soap) and the total inert ingredients is required by the Federal insecticide act of 1910, purchasers are advised of the amount of soap and water present. In general fish-oil soap should be used against aphids at the rate of 1 pound to from 5 to 7 gallons of water, depending upon the amount of water present in the soap.

KEROSENE EMULSION.

Kerosene emulsion is made up in stock solution according to the following formula:

Kerosene	gallons	2
Fish-oil or laundry soap	pound	½
Water	gallon	1

First the soap should be dissolved in a gallon of boiling water, and after the vessel is removed from the fire the coal oil should be added. Then the mixture should be agitated thoroughly for four or five minutes by pumping the liquid back into itself until it becomes a creamy mass and the oil does not separate. The quantities of the ingredients

[1] The name "fish-oil soap" is now used in place of "whale-oil soap," since most of the soap on the market is made of fish oil.

may be increased when a larger quantity of spray is needed. This stock solution is used against aphids at the rate of 1 gallon to 7 or 8 gallons of water. Kerosene emulsion should not be added to a lime-sulphur spray.

SPRAYING FOR APPLE APHIDS.

Experiments made by the Bureau of Entomology and several of the agricultural experiment stations, notably those of Colorado and Oregon and the Geneva, N. Y., station, show that the aphids attacking the fruit and foliage of the apple are best controlled by spraying in the early spring just as the buds are breaking to destroy the stem-mothers. At this time the insects are hatching from the winter eggs, and are so exposed that one thorough treatment should destroy from 95 to 98 per cent of them and prevent their increase to such an extent that they will not cause serious injury later in the season. This applies especially to the oat aphis, the rosy aphis, and the clover aphis.

In the case of the green apple aphis, which lives on the apple throughout the year, the suppression of stem-mothers in the spring does not always guarantee freedom from this insect during midsummer, and supplementary treatments sometimes are desirable. In the case of young orchards, where the green apple aphis is principally to be considered, the bud spray should be given, but additional applications should be made in summer if found necessary.

Figure 29 illustrates the condition of apple buds when the first spraying should be done, and figure 30 shows the buds too far advanced for successful work, as the aphids have penetrated the spreading leaves and are very hard to reach. In the bud spray the nicotine may be used in the winter strength lime-sulphur solution employed for the San Jose scale, thus effecting the control of both insects by the one application. If the bud spray has been omitted and the aphids are present in numbers, 40 per cent nicotine sulphate should be used in the dilute lime-sulphur solution which is used for the first scab spray and also for the codling moth spray following the dropping of the blossoms. These later applications, however, are not nearly so valuable as the bud spray and merely serve to check the insects.

In spraying apple aphids very thorough work is essential, with good pump pressure, so that the spray may be driven as much as possible against the insects. Results in spraying will vary, depending upon the size of the trees as affecting the thoroughness of the application. On large trees results are frequently less satisfactory than on medium and smaller trees.

Spraying in the fall for the destruction of the fall migrants and the egg-laying females has been tried to a limited extent, but the adequacy of the treatment has not yet been proven.

Annual bud spraying of apple orchards would appear to be good practice, and over a series of years would no doubt prove profitable. This is especially true of varieties subject to "fruit spots" or "stigmonose," since these troubles have been shown by the Bureaus of Plant Industry and Entomology to be due, in part at least, to the activities of aphids.

FIG. 29.—Young stem-mothers of an apple aphid and condition of buds when the bud spraying should be given. Enlarged. (Original.)

CONTROL OF APHIDS ON PLUM, PEACH, CHERRY, ETC.

The several aphids which occur on plum, as well as the green peach aphis, pass the winter on the trees in the egg stage, hatching in the spring about the time when foliage appears. None of these species curls the foliage to the same extent as do some of the apple aphids, and thorough spraying of the trees when the insects are in evidence usually will be satisfactory. Nevertheless spring spraying against the stem-mothers is desirable in orchards where the insects have been troublesome regularly or where winter eggs are seen to be present in numbers.

The black peach aphis, which winters on the roots of the peach, should be treated as soon as the insects are observed to be present on the foliage and twigs, and in regions where they are likely to be troublesome, as on nursery stock in sandy situations, careful watch should be made for their first appearance.

The black cherry aphis is likely to be in evidence each year on cherries. The insect winters on the trees in the egg stage and the eggs hatch somewhat in advance of the opening of the buds. Since this species causes a decided curling of foliage so that later treatments are not satisfactory, the effort should be made to destroy the stem-mothers as the buds are breaking.

FIG. 30.—Young apple shoot too far expanded for successful aphid spraying. Enlarged. (Original.)

DESTRUCTION OF WINTER EGGS.

Considerable experimenting has been done with sprays during the dormant period of trees to destroy the winter eggs of aphids (fig. 8), on the shoots, twigs, and branches. Thus far results have not been satisfactory, and while sprays may result in the destruction of some of the eggs, serious aphid injury occurs very frequently in orchards well sprayed for the San Jose scale.

In the course of pruning young trees it is often possible to remove many shoots covered with eggs, which should be destroyed.

CONTROL OF APHIDS ON CURRANT, GOOSEBERRY, AND GRAPE.

All of the important aphids attacking the currant and gooseberry pass the winter on these plants in the egg stage, the stem-mothers hatching as the leaf buds are opening and soon causing the leaves to become more or less pitted or curled. It is especially important, therefore, to spray as the shoots are pushing out, to destroy the stem-mothers before they are protected by the distorted foliage. In spraying for these insects later in the season the liquid should be directed upward to wet the insects on the underside of the leaves.

The grapevine aphis, while often abundant on the terminal growth, is rarely very injurious. It is much subject to parasitic and predatory enemies, and migrates from the grape to Viburnum in early fall. When so abundant as to require treatment, any of the contact insecticides may be used.

CLEAN CULTURE.

As the reader will have learned, most aphids have a winter and early spring host plant, and from this they migrate to other plants, on which they subsist for several weeks or months during the summer. In most instances this alternation of food plants is essential to the life of the species, and in general the aphids are most troublesome in regions where alternate hosts are present in abundance. Often one or more of the host plants are of little or no economic importance in the locality, and in some cases are troublesome weeds. The destruction of worthless plants is desirable and should serve materially to reduce the aphids in question. Thus, in the case of the rosy aphis, the alternate food plants of which are species of plantain, the destruction of these in and about orchards is especially desirable, and should be a part of the remedial work against this pest in localities where it is more or less chronically injurious.

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THE TOBACCO BUDWORM AND ITS CONTROL

IN THE SOUTHERN TOBACCO DISTRICTS

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FARMERS' BULLETIN 819

UNITED STATES DEPARTMENT OF AGRICULTURE

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

Washington, D. C. July, 1917

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BUDWORMS eat holes through the tips of leaves in the developing bud of the tobacco plant, in both open and covered fields, reduce the yield, and render the product practically worthless except for cigar filler and plug filler. The seed also is injured.

The "worms," or larvæ, hatch from eggs laid on the leaves by a greenish moth, and injury begins as soon as they have migrated from the leaves to the bud—usually in about 24 hours.

Control measures, described on pages 6–11 of this bulletin, may be summarized as follows:

Remove from the fields and burn suckers picked from the plants.

Cut and burn plants as soon after harvesting as possible.

Plow as soon as possible after removal of the plants.

When fields are shaded with cheesecloth provide cloth-covered gates and keep them closed, to exclude the budworm moths. Patch promptly all holes in cheesecloth shades.

Destroy plants in seed beds as soon as possible after a sufficient number have been taken for use in the fields.

Cover all seed beds with cheesecloth to exclude the moths.

As soon as plants have become established in the field apply arsenate of lead and corn meal (1 pound of arsenate of lead to 75 pounds of the meal) to the buds. Continue applications twice a week until the plants are topped.

THE TOBACCO BUDWORM[1] AND ITS CONTROL IN THE SOUTHERN TOBACCO DISTRICTS.

CONTENTS.

One of the most important insect pests of tobacco, particularly in the South, is the tobacco budworm (fig. 1). The presence of this pest in tobacco fields, even in very small numbers, may result in great damage to the crop. A thorough knowledge by the planter of the correct methods of control of this insect therefore is essential, especially in areas where the cultivation of tobacco for cigar purposes is practiced.

Since the results of budworm attack on sun-grown and shade-grown tobacco are the same, the control measures outlined herein apply equally to both.

DESCRIPTION OF THE INSECT IN ITS DIFFERENT STAGES.

The tobacco budworm passes through four distinct stages in the course of its development—the egg, larva, pupa, and adult. The eggs are small, whitish, nearly dome-shaped objects, measuring about one-fiftieth of an inch in diameter. They are sculptured with radiating ribs and cross furrows.

The larva, or worm stage (fig. 1, *b*, *c*), is greenish with pale stripes running lengthwise of the body. Small larvæ which have passed through only one or two molts are much lighter in color than those which have fed more extensively and have cast their skins a greater number of times. When first hatched the larva measures about one-twentieth of an inch; when full grown and ready to burrow into the soil for pupation it is about an inch and a half in length.

[1] *Chloridea virescens* Fab.; order Lepidoptera, family Noctuidae. It was formerly known as *Heliothis rhexiae* S. & A.

The pupa, or quiescent stage (fig. 1, *e*), which is spent in the ground, measures about three-fourths of an inch in length and is brown—almost the color of mahogany.

The adult, or parent (fig. 1, *a*), of the budworm is easily distinguished from other insects found in tobacco fields. It is a greenish moth with a wing spread of about 1½ inches. The forewings are of a beautiful greenish color, obliquely crossed with three lighter lines, and the hind wings are whitish, bordered with a brownish fringe.

NATURE AND EXTENT OF INJURY.

Injury to the plants, which is entirely the work of the larvæ, or worms (fig. 1, *b*, *c*), takes place as soon as the tiny larvæ, hatching from eggs laid on the leaves, reach the bud, although usually it is several days before planters become aware of the damage. The leaves of the bud have then developed somewhat, and examination reveals the presence of the small holes, which have increased in size. When these holes are made in the tips of the leaves in the developing bud, misshapen leaves often result; when the attack is made elsewhere, large unsightly holes develop as the leaf tissue expands. In both cases the leaves are unfit for cigar wrapper and must be placed in the lower grades, often at a loss of as much as $1 a pound. In growing tobacco for cigar purposes it is necessary to produce entire leaves. So complete would be the loss in Georgia and Florida if no control measures were practiced against the budworm that the industry would have to be abandoned. Before the present investigation was begun the budworm was controlled entirely by use of the Paris green and meal mixture. In spite of the use of this insecticide as the means of control, the average loss per acre in shade-grown tobacco was estimated at $37.50. This was due in part to burning by the poison and in part to incomplete control of the insect.

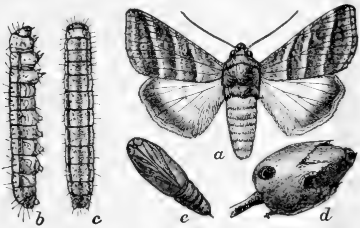

FIG. 1.—The tobacco budworm (*Chloridea virescens*): *a*, Adult, or moth; *b*, *c*, full grown larva, from side and from above; *d*, seed pod bored into by larva; *e*, pupa. Natural size. (Howard.)

HISTORY AND DISTRIBUTION IN THE UNITED STATES.

The tobacco budworm is a very serious pest in the tobacco-growing sections of Florida, Georgia, Alabama, and Louisiana. Although common in North Carolina, South Carolina, and Virginia, it is much less injurious there than in the more southern part of its range. It is rarely injurious in Kentucky and Tennessee. It has been recorded from Missouri, Ohio, and Connecticut. Perhaps the earliest record of injury by this insect dates back to 1797. At that time Smith and Abbot[1] wrote as follows: "[This species] eats the bud and blossoms of Rhexia, as well as of tobacco; to the latter it is very pernicious in Virginia and other places, as it destroys the main shoot."

In Georgia in 1886 it was reported by a planter to have been more injurious to tobacco than the hornworms.[2]

SEASONAL HISTORY.

Eggs and larvæ are present in tobacco fields in Florida and Georgia throughout the growing season. Larvæ have been observed as late as August 1 on plants growing within and around old seed beds.

Eggs are deposited singly on the leaves, usually on the underside. In Florida, during the growing season of tobacco, they hatch in from three to five days. Newly hatched larvæ first feed sparingly on the shells of eggs from which they have issued and then eat small areas about the size of a pinhead from the leaf surface. These minute budworms then begin a migration and reach the bud of the plants in about 24 hours. They often stop to feed two or three times but eat only one or two layers of the leaf cells and do no appreciable injury until they reach the bud.

When the bud is reached the characteristic injury is wrought. The young budworms conceal themselves between the immature, unfolding leaves and begin to feed very greedily. They are so small and so well concealed that they can be detected only by the very closest scrutiny, and if a dose of poison mixture has not been placed in the bud before their arrival extensive injury will have been done before any remedial measure can be made effective.

The larva or worm stage has been found to cover a period of from 18 to 31 days during May and June, at the end of which the mature larvæ burrow into the soil and pupate. The length of the pupa stage may vary during the summer, covering a period of from 13 to 21 days. The emergence of adults from the ground is affected materially by moisture conditions, for it has been observed that a great many moths often appear at the expiration of a dry period.

After the moths emerge a period of from four to five days may elapse before egg laying begins. Moths kept in captivity laid an average of 334 eggs. From observations during May and June of 1916 the average duration of the life cycle was determined to be $37\frac{1}{2}$ days.

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[1] Smith, Sir James Edward. The Natural History of the Rarer Lepidopterous Insects of Georgia. 1797.

[2] *Phlegethontius sexta* Joh. and *P. quinquemaculata* Haw.

FOOD PLANTS.

Besides feeding on tobacco the budworm has been recorded in the United States as attacking deer grass,[1] geranium, and ageratum. It has been reported as feeding upon wild solanaceous plants, including ground cherry[2] and other species of the same genus, and *Solanum seiglinge.*

Fig. 2.—Stick and cup method of applying poison mixture in the tobacco bud in combatting the budworm early in the season before the bud leaves have become folded.

INSECT ENEMIES.

Certain wasps have been observed to destroy the larger larvæ, but the most important enemy of the budworm is a small wasplike insect[3] which deposits its eggs in the bodies of the larvæ. This results finally in the death of the budworm. The parasitic insects may be seen continually flying from plant to plant examining the buds in search of budworms. Many farmers mistake these insects for the adult form of the budworm and often destroy them. Having seen the parasites enter the buds and fly away, the planters have examined the buds and, having found the small budworms within, have supposed that they were left there by the parasites.

CONTROL MEASURES.

POISON APPLICATIONS.

It is evident from the habits of the budworm that the most feasible means of direct control are applications of some insecticide in the bud. Experience has shown that at least two applications a week

[1] *Rhexia virginica.* [2] *Physalis viscosa.* [3] *Toxoneura* sp.

are necessary in order fully to protect the bud, because the poison is scattered by the expansion of the rapidly developing leaves. The first two or three applications are made by means of the stick and cup method (fig. 2). A quart cup with nail holes in the bottom is fastened to a stick and the poison mixture is sifted upon each plant as the operator walks slowly along the row. As the plants increase in size the leaves of the bud are more tightly folded and it becomes necessary to change the method of application by opening the bud with one hand and at the same time dropping a small portion of the poison mixture into the bud with the other hand. The poison is carried in a sack fastened around the waist. (See illustration on title page.)

OBJECTIONS TO THE USE OF PARIS GREEN.

The insecticide in use in Florida at the time of the institution of experiments by the Bureau of Entomology was a mixture of 1 pound of Paris green to 150 pounds of corn meal. About 12 to 14 pounds per acre of this mixture is necessary for each application. The applications must be continued from the time tobacco is set until it is topped.

Shade-grown tobacco is very tender and very susceptible to injury from either a mechanical or a chemical source. In dry weather Paris green causes very little damage, but in wet weather considerable injury may result from the comparatively excessive amounts that wash down and collect in the bud and in the axils of the leaves. Planters are familiar with this condition and attempt to avoid injury by making lighter applications. When such a course is adopted some of the poison injury is eliminated but extra damage from budworm attack follows on account of the insufficient dosage. When Paris green mixture is used there is always the possibility of damage either from the action of the poison on the leaves or from budworm attack following the application of insufficient quantities of the mixture. The normal injury also is increased frequently because some laborers apply more of the mixture than is necessary for budworm control.

RELATIVE EFFICIENCY AND ECONOMY IN THE USE OF VARIOUS POISONS.

Owing to this danger of injury to the leaves by Paris green when used in sufficient amounts, and the imperfect protection afforded by smaller quantities, the discovery of a poison that would be safer under all conditions of weather and of application, and one that would, at the same time, give the greatest budworm control was much to be desired. During the seasons from 1913 to 1916, inclusive, experiments were performed with at least 30 mixtures, including the following poisons, some of which have been used more or less commonly against the budworm: Arsenate of lead, antimony sulphid, Paris green, tri-potassium arsenate, ortho-arsenite of zinc, antimony arsenate, and antimony oxid. These were tested in varying strengths and in combination with corn meal, gypsum, and fuller's earth as carriers. Of all the poisons used, Paris green, arsenate of lead, and golden antimony sulphid gave the most promising results, although there is a great variation in the efficiency and cost of application of these poisons. Corn meal was found to be the most satisfactory carrier.

Table 1 indicates the relative average cost per acre per season of antimony sulphid, arsenate of lead, and Paris green, as well as the percentage of leaves free of budworm and poison injury. The cost data are based upon results obtained on 51 plantations where 476 acres of tobacco were treated throughout the season. It was found that an average of 4.17 bushels of meal were necessary to the treatment of 1 acre. In calculating the total cost for the treatment of an acre, corn meal was valued at $1 per bushel. The prices per pound of antimony sulphid, arsenate of lead, and Paris green were taken as 35 cents, 25 cents, and 30 cents, respectively.

TABLE 1.—*Relative efficiency and economy of antimony sulphid, arsenate of lead, and Paris green in controlling the tobacco budworm.*

Poison used.	Cost of poison.	Cost of meal.	Cost of labor.	Total cost per acre per season.	Per cent of leaves free of budworm and poison injury.
Antimony sulphid, 1 pound; corn meal, 24 pounds	$2.92	$4.17	$2.25	$9.34	98.35
Arsenate of lead, 1 pound; corn meal, 75 pounds	.66	4.17	2.25	7.08	98.25
Paris green, 1 pound; corn meal, 150 pounds	.40	4.17	2.25	6.82	92.50

From the foregoing table it will be seen that where antimony sulphid had been used at the rate of 1 pound to 24 pounds of corn meal, 98.35 per cent of the leaves were free from budworm and poison injury; and that where arsenate of lead had been used at the rate of 1 pound to 75 pounds of corn meal, 98.25 per cent of the leaves were perfect. The cost of the applications of antimony sulphid per acre per season was $2.26 more than for the arsenate of lead, and of course the difference of one-tenth of 1 per cent in the efficiency of these applications in favor of the antimony sulphid would not compensate for the extra expense.

Where Paris green had been used at the rate of 1 pound to 150 pounds of corn meal, 92.5 per cent of the leaves were free from injury—5.75 per cent less than where arsenate of lead had been applied—but the cost of application per acre per season was 26 cents less than for the arsenate of lead. Since the injury following the use of Paris green has been shown to result in a loss of $37.50 per acre, and arsenate of lead has been shown to save $28.75 of this amount, the actual saving due to the use of arsenate of lead is $28.75 minus 26 cents (for arsenate of lead costs 26 cents per acre more than does Paris green), or $28.49. It will be understood, therefore, that the possibility of incurring a loss of $37.50 per acre will not justify the use of Paris green to effect a saving in material of 26 cents per acre.

A mixture of 1 pound of arsenate of lead and 75 pounds of corn meal has proved to be the most efficient combination against budworms. As already stated, on account of the method of application necessary in controlling budworms, there must be some variation in the quantity applied to each bud. The arsenate of lead and corn meal mixture can be employed without fear of injury in case too great a quantity is used.

Poisons mixed with corn meal are more readily fed upon by budworms than those mixed with other carriers. Then, too, corn meal is the most desirable material for this purpose because it does not interfere with the development of the immature leaves. Even when saturated during periods of showers, corn meal does not become compact and cause damage such as takes place when other carriers are used.

Tests have shown also that the efficiency of arsenate of lead when employed against the budworm varies with the carrier with which it is used, as indicated in Table 2.

TABLE 2.—*Relative efficiency against the tobacco budworm of arsenate of lead with different carriers.*

Poison.	Experiment No.	Budworm injury.
		Per cent.
Arsenate of lead, 1 pound; corn meal, 75 pounds	1	0.79
Arsenate of lead, 1 pound; gypsum, 25 pounds	2	3.00
Arsenate of lead, 1 pound; Fuller's earth, 16 pounds	3	2.50

In experiment No. 1 arsenate of lead was used at the rate of 1 pound to 75 pounds of corn meal and only 0.79 per cent of leaves showed injury. In experiment No. 2 the arsenate of lead was used three times as strong as in experiment No. 1 (1 pound to 25 pounds) but with gypsum as a carrier. Three per cent of the leaves were injured—nearly four times as many as in experiment No. 1. In experiment No. 3 the arsenate of lead was used nearly five times as strong as in experiment No. 1, yet the leaf injury amounted to 2.5 per cent—more than three times that in experiment No. 1. These experiments indicate that of the three carriers corn meal is preferable in budworm control.

GENERAL RECOMMENDATIONS.

Suckers on plants usually become infested with budworms. When these are removed no care is taken to destroy the infesting larvæ. In one case where suckers were being removed and thrown between the rows 55 per cent were found to be infested. Many of these larvæ may develop to pupæ and later to moths. Suckers should be taken from the fields and burned.

At the end of the growing season tobacco plants from which the marketable leaves have been removed are often allowed to remain standing in the fields. These provide breeding places for the budworms. As soon as possible after harvesting is completed plants should be cut and burned, to destroy the larvæ and pupæ infesting them. This practice has been adopted by some planters who use the ash to good advantage for fertilizer ingredients.

Where tobacco is grown under cheesecloth, preventive measures against budworm attack may be practiced with a great deal of success. In such cases care should be taken to patch holes in the cloth. Since it is necessary to provide openings in these shades through which workmen with farm animals and implements may come and go, gates covered with cheesecloth should be provided, and kept closed as much as possible so as to exclude the moths, or adults, of the budworm.

Plants frequently are left growing within and around old seed beds. These invariably are infested and contribute considerably to the abundance of moths which deposit eggs on plants within the fields. Plants about the seed bed should be destroyed therefore as soon as the seed bed is abandoned.

Seed beds should always be covered and walled in with cloth so as to prevent the entrance of moths. In this way the number of eggs introduced into the fields on the plants will be held to a minimum.

Because of the nature of attack of this tobacco pest much care is necessary in direct-control practices. Experience has shown that a slight delay in making poison applications often results in great damage to the crop. The necessity of applying the mixture directly to the leaves of the bud can not be too greatly emphasized. The effects of careless manipulation may be almost as bad as if no control measures were attempted. Planters should keep these points clearly in mind because the difference between a valuable tobacco crop and one of less than ordinary quality is often dependent upon the care with which budworm control is practiced.

Direct control in Florida and Georgia should begin as soon as possible after the plants have become established in the field. Applications of the poison mixture should be made in the buds from then until the plants have been topped. It is of special importance to emphasize the necessity of beginning the applications of the poison mixture as soon as the plants are set in the field. A delay in starting this work may give time for the eggs that are introduced from the seed beds to hatch, and for the young larvæ (young budworms) to reach the bud and do considerable damage. For the best results the buds must be treated twice a week until topping has been completed.

The best mixture which has been employed in experiments under actual field conditions is 1 pound of arsenate of lead and 75 pounds of corn meal. In the preparation of this mixture care should be taken to obtain an even distribution of the poison throughout the corn meal. For this purpose mechanical mixers have been employed where great quantities are necessary. These, however, are not essential, for with a little extra care the mixtures can be prepared quite as well by hand.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING TO INSECTS INJURIOUS TO TOBACCO.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Arsenate of Lead as an Insecticide Against the Tobacco Hornworms in the Dark-tobacco District. (Farmers' Bulletin 595.)
The Tobacco Beetle and how to Prevent Loss from It. (Farmers' Bulletin 846.)
Tobacco Splitworm. (Department Bulletin 59.)
Methods of Controlling Tobacco Insects. (Entomology Circular 123.)

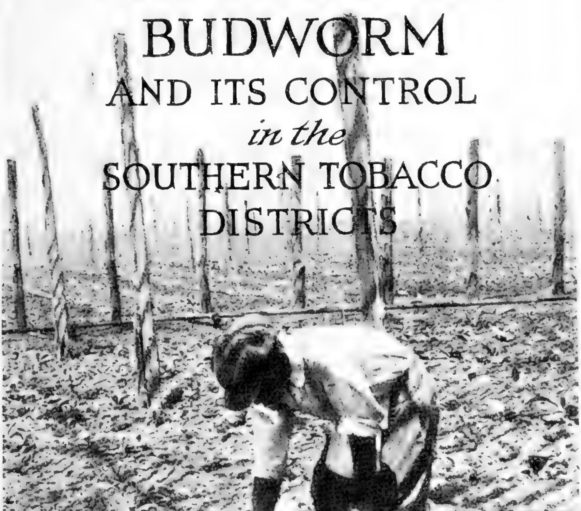
FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

So-called Tobacco Wireworm in Virginia. (Department Bulletin 78.) 1914. Price, 5 cents.
Tobacco Thrips and Remedies to Prevent "White Veins" in Wrapper Tobacco. (Entomology Circular 68.) 1906. Price, 5 cents.
Tobacco Thrips, a New and Destructive Enemy of Shade-grown Tobacco. (Entomology Bulletin 65.) 1907. Price, 5 cents.
Principal Insects Affecting Tobacco Plant. (Farmers' Bulletin 120.) 1900. Price, 5 cents.

U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 819

The TOBACCO BUDWORM AND ITS CONTROL *in the* SOUTHERN TOBACCO DISTRICTS



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Control measures, described on pages 7–11 of this bulletin, may be summarized as follows:

Cut and plow under the tobacco stalks as soon as possible after harvesting.

When fields are shaded with cheesecloth, provide cloth-covered gates and keep them closed, to exclude the budworm moths. Patch promptly all holes in cheesecloth shades.

Destroy plants in seed beds as soon as possible after a sufficient number have been taken for use in the fields.

Cover all seed beds with cheesecloth to exclude the moths.

As soon as plants have become established in the field, apply arsenate of lead and corn meal (1 pound of arsenate of lead to 75 pounds of the meal) to the buds. Continue applications twice a week until the plants are topped.

Washington, D. C. Issued July, 1917; revised February, 1923

THE TOBACCO BUDWORM[1] AND ITS CONTROL IN THE SOUTHERN TOBACCO DISTRICTS.[2]

A. C. MORGAN, *Entomologist*, and F. L. McDONOUGH,[3] *Scientific Assistant, Southern Field Crop Insect Investigations, Bureau of Entomology.*

CONTENTS.

ONE of the most important insect enemies of tobacco, particularly in the South, is the tobacco budworm (Fig. 1). The presence of this pest in tobacco fields, even in very small numbers, may result in great damage to the crop. A thorough knowledge by the planter of the correct methods of control of this insect therefore is essential, especially in areas where the cultivation of tobacco for cigars is practiced.

Since the results of budworm attack on sun-grown and shade-grown tobacco are the same, the control measures outlined herein apply equally to both.

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The tobacco budworm passes through four distinct stages in the course of its development—the egg, larva, pupa, and adult. The eggs are small, whitish, nearly dome-shaped objects, measuring about one-fiftieth of an inch in diameter. They are sculptured with radiating ribs and cross furrows.

The larva or worm stage (Fig. 1, *b*, *c*) varies greatly in color. The most common color is light green with paler stripes running lengthwise of the body, but the color may vary from green to yellowish, dark reddish brown, or even a very dark gray. Between these extremes there are many combinations of colors. Small larvæ which have passed through only one or two molts are much lighter in color than those which have fed more extensively and have cast their skins a greater number of times. When first hatched the larva measures about one-twentieth of an inch; when full-grown and ready

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[2] Revised by F. S. Chamberlin, scientific assistant, Southern Field Crop Insect Investigations, Bureau of Entomology.

[3] Resigned October 31, 1919.

to burrow into the soil for pupation it is about an inch and a half long.

The pupa, or quiescent stage (Fig. 1, *e*), which is spent in the ground, measures about three-fourths of an inch in length and is brown—almost the color of mahogany.

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NATURE AND EXTENT OF INJURY.

Injury to the plants, which is entirely the work of the larvæ, or worms (Fig. 1, *b*, *c*), takes place as soon as the tiny larvæ, hatching from eggs laid on the leaves, reach the bud, although usually it is several days before planters become aware of the damage. The leaves of the bud have been developed somewhat, and examination reveals the presence of the small holes, which have increased in size. When these holes are made in the tips of the leaves in the developing bud, misshapen leaves often result; when the attack is made elsewhere large, unsightly holes develop as the leaf tissue expands (Fig. 2). In both cases the leaves are unfit for cigar wrappers, and must be placed in the lower grades, often at a loss of as much as $1 a pound. In growing tobacco for cigars it is necessary to produce entire leaves. So complete would be the loss in Georgia and Florida if no control measures were practiced against the budworm that the industry would have to be abandoned. Before the present investigation was begun the budworm was controlled entirely by use of the Paris green and meal mixture. In spite of the use of this insecticide as a means of control, the average loss per acre in shade-grown tobacco was estimated at $37.50. This was due in part to burning by the poison and in part to incomplete control of the insect.

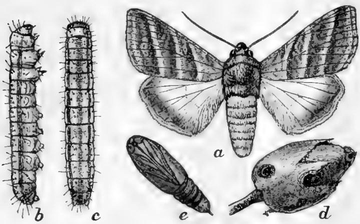

FIG. 1.—The tobacco budworm: *a*, Adult, or moth; *b*, *c*, full grown larva, from side and from above; *d*, seed pod bored into by larva; *e*, pupa. Natural size. (Howard.)

HISTORY AND DISTRIBUTION IN THE UNITED STATES.

The tobacco budworm is a very serious pest in the tobacco-growing sections of Florida, Georgia, Alabama, and Louisiana. Although common in North Carolina, South Carolina, and Virginia, it is much less injurious there than in the more southern part of its range. It is rarely injurious in Kentucky and Tennessee. It has been recorded from Missouri, Ohio, and Connecticut. Perhaps the earliest record of injury by this insect dates back to 1797. At that time Smith and

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In Georgia in 1886 it was reported by a planter to have been more injurious to tobacco than the hornworms.[5]

SEASONAL HISTORY.

Eggs and larvæ are present in tobacco fields in Florida and Georgia throughout the growing season. Moths often appear early enough in the spring to infest seed beds, and by setting-out time eggs are being deposited in large numbers. From the end of the growing season until the middle of August, larvæ are abundant upon stalks and suckers left standing in the fields. From this time on their numbers decline very rapidly, although they have been observed as late as November 23 at Quincy, Fla.

Eggs are deposited singly on the leaves, usually on the underside. In Florida, during the growing season of tobacco, they hatch in from three to five days. Newly hatched larvæ first feed sparingly on the shells of eggs from which they have issued and then eat small areas about the size of a pinhead from the leaf surface. These minute budworms then begin a migration and reach the bud of the plant in about 24 hours. They often stop to feed two or three times, but eat only one or two layers of the leaf cells and do no appreciable injury until they reach the bud.

When the bud is reached the characteristic injury is wrought. The young budworms conceal themselves between the immature, unfolding leaves and begin to feed very greedily. They are so small and so well concealed that they can be detected only by the very closest scrutiny, and if a dose of poison mixture has not been placed in the bud before their arrival extensive injury will have been done before any remedial measure can be made effective.

The larva or worm stage has been found to cover a period of from 18 to 31 days during May and June, at the end of which the mature larvæ burrow into the soil and pupate. The length of the pupa stage may vary during the summer, covering a period of from 13 to 21 days. The emergence of adults from the ground is affected materially by moisture conditions, for it has been observed that a great many moths often appear at the expiration of a dry period.

After the moths emerge a period of from four to five days may elapse before egg laying begins. Moths kept in captivity laid an average of 334 eggs. From observations during May and June of 1916 the average duration of the life cycle was determined to be 37½ days.

FOOD PLANTS.

Besides feeding on tobacco, the budworm has been recorded in the United States as attacking okra, deer grass,[6] geranium, and ageratum. It has been reported as feeding upon wild solanaceous plants, including ground cherry[7] and another species of the same genus.

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[4] Smith, Sir James Edward. The Natural History of the Rarer Lepidopterous Insects of Georgia. 1797.

[5] *Protoparce sexta* Joh. and *P. quinquemaculata* Haw.

[6] *Rhexia virginica.*

[7] *Physalis viscosa.*

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Continued observations in the Florida shade-tobacco district, however, have made it apparent that in this region, at least, the tobacco budworm feeds sparingly, if at all, upon plants other than tobacco with the exception of beggarweed, which is fed upon to some extent during the fall months.

PREDACIOUS AND PARASITIC ENEMIES.

One of the important enemies of the tobacco budworm is a greenish spider,[8] which is extremely common on tobacco stalks in the South.

A certain wasp[9] also destroys many of the larger larvæ.

A fly[10] closely resembling the common house fly acts as a parasitic enemy of the budworm. This fly deposits eggs upon the body of the

FIG. 2.—Injury to tobacco plant by the tobacco budworm.

worm. These eggs hatch into tiny maggots, which burrow into the body of their host and after feeding there for some time finally destroy it.

The most important parasite of the tobacco budworm, however, is a small, black-winged, red-bodied, wasplike insect[11] which deposits its eggs in the bodies of the larvæ. These eggs hatch into maggots which ultimately destroy the worm. This parasitic insect may be seen continually flying from plant to plant examining the buds in search of budworms. Many farmers mistake these insects for the adult form of the budworm and often destroy them. Having seen the parasites enter the buds and fly away, the planters have examined the buds and, having found the small budworm within, have supposed that they were left there by the parasite.

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[8] *Peucetia viridans* Hentz.

[9] *Polistes bellicosus* Cress.

[10] *Sarcophaga sternodontis* Townsend.

[11] *Toxoneura* sp.

CONTROL MEASURES.

POISON APPLICATIONS.

It is evident from the habits of the budworm that the most feasible means of direct control are applications of some insecticide in the bud. Experience has shown that at least two applications a week are necessary in order fully to protect the bud, because the poison is scattered by the expansion of the rapidly developing leaves. The first two or three applications are made by the stick-and-cup method (Fig. 3). A quart cup with nail holes in the bottom is fastened to a stick and the poison mixture is sifted upon each plant as the operator walks slowly along the row. As the plants increase in size the leaves of the bud are more tightly folded and it becomes necessary to change the method of application by opening the bud with one hand and at the same time dropping a small portion of the poison mixture into the bud with the other hand. The poison is carried in a sack fastened around the waist. (See illustration on title page.)

Fig. 3.—Stick and cup method of applying poison mixture in the tobacco bud in combating the budworm early in the season before the bud leaves have become folded.

OBJECTIONS TO THE USE OF PARIS GREEN.

The insecticide in use in Florida at the time experiments by the Bureau of Entomology were begun was a mixture of 1 pound of Paris green to 150 pounds of corn meal. About 12 to 14 pounds per acre of this mixture is necessary for each application. The applications must be continued from the time tobacco is set until it is topped.

Shade-grown tobacco is very tender and very susceptible to injury from either a mechanical or a chemical source. In dry weather Paris green causes very little damage, but in wet weather considerable injury may result from the comparatively excessive amounts that wash down and collect in the bud and in the axils of the leaves. Planters are familiar with this condition and attempt to avoid injury by making lighter applications. When such a course is adopted some of the poison injury is eliminated, but extra damage from budworm attack follows on account of the insufficient dosage. When Paris-green mixture is used there is always the possibility of damage, either from the action of the poison on the leaves or from budworm attack following the application of insufficient quantities of the mixture. The normal injury also is increased frequently because some laborers apply more of the mixture than is necessary for budworm control.

RELATIVE EFFICIENCY AND ECONOMY IN THE USE OF VARIOUS POISONS.

Owing to this danger of injury to the leaves by Paris green when used in sufficient amounts, and the imperfect protection afforded by smaller quantities, the discovery of a poison that would be safer under all conditions of weather and of application, and one that would at the same time give the greatest budworm control, was much to be desired.

During the seasons from 1913 to 1922, inclusive, experiments were performed with a large number of mixtures, including the following poisons, some of which have been used more or less commonly against the budworm: Arsenate of lead, arsenate of calcium, magnesium arsenate, antimony sulphid, Paris green, tripotassium arsenate, orthoarsenite of zinc, antimony arsenate, and antimony oxid.

These were tested in varying strengths and in combination with corn meal, gypsum, and fuller's earth as carriers. Of all the poisons used, Paris green, arsenate of lead, and golden antimony sulphid gave the most promising results, although these poisons differed greatly in efficiency and cost of application. Corn meal was found to be the most satisfactory carrier.

Table 1 indicates the average cost per acre per season of antimony sulphid, arsenate of lead, and Paris green, as well as the percentage of leaves free from budworm and poison injury. The cost data are based upon results obtained on 51 plantations, where 476 acres of tobacco were treated throughout the season. It was found that an average of 4.17 bushels of meal were necessary to the treatment of 1 acre. In calculating the total cost for the treatment of an acre, corn meal was valued at $1 per bushel (48 pounds). The prices per pound of antimony sulphid, arsenate of lead, and Paris green were taken as 35 cents, 25 cents, and 30 cents, respectively.

TABLE 1.—*Relative efficiency and economy of antimony sulphid, arsenate of lead, and Paris green in controlling the tobacco budworm.*

Poison used.	Cost of poison.	Cost of meal.	Cost of labor.	Total cost per acre per season.	Per cent of leaves free from budworm and poison injury.
Antimony sulphid, 1 pound; corn meal, 24 pounds	$2.92	$4.17	$2.25	$9.34	98.35
Arsenate of lead, 1 pound; corn meal, 75 pounds	.66	4.17	2.25	7.08	98.25
Paris green, 1 pound; corn meal, 150 pounds	.40	4.17	2.25	6.82	92.50

From Table 1 it will be seen that where antimony sulphid had been used at the rate of 1 pound to 24 pounds of corn meal, 98.35 per cent of the leaves were free from budworm and poison injury; and that where arsenate of lead had been used at the rate of 1 pound to 75 pounds of corn meal, 98.25 per cent of the leaves were perfect. The cost of the applications of antimony sulphid per acre per season was $2.26 more than for the arsenate of lead, and of course the difference of one-tenth of 1 per cent in the efficiency of these applications in favor of the antimony sulphid would not compensate for the extra expense.

Where Paris green had been used at the rate of 1 pound to 150 pounds of corn meal, 92.5 per cent of the leaves were free from injury—5.75 per cent less than where arsenate of lead had been applied—and the cost of application per acre per season was 26 cents less than for the arsenate of lead. The injury following the use of Paris green has been shown to result in a loss of $37.50 per acre. In studies made in the Bureau of Entomology arsenate of lead has been shown to save $28.75 of this amount. The actual saving due to the use of arsenate of lead is $28.75 minus 26 cents (for arsenate of lead costs 26 cents per acre more than does Paris green), or $28.49. It will be understood, therefore, that the possibility of incurring a loss of $37.50 per acre will not justify the use of Paris green to effect a saving in material of 26 cents per acre.

A mixture of 1 pound of arsenate of lead and 75 pounds of corn meal has proved to be the most effective combination against budworms. As already stated, on account of the method of application necessary in controlling budworms, it is impossible to avoid some variation in the quantity applied to each bud. The arsenate of lead and corn meal mixture can be employed without fear of injury in case any amount within reason is used.

Poisons mixed with corn meal are more readily fed upon by budworms than those mixed with other carriers. This material appears to be attractive to the worm, apparently serving as a bait, whereas other carriers seem more or less distasteful. Then, too, corn meal is the most desirable material for this purpose because it does not interfere with the development of the immature leaves. Even when saturated during periods of showers, corn meal does not often become compact and cause damage such as takes place when other carriers are used.

As calcium arsenate is now being used rather extensively throughout the South as a poison for the cotton boll weevil, a word of warning may be needed in regard to its use in a budworm poison mixture. Calcium arsenate has been tried with various carriers and in various strengths over a period of several years and has invariably given unsatisfactory results.

Even in very dilute quantities, calcium arsenate burns tobacco severely, especially in rainy weather, and if used strong enough to serve as an effective poison it usually causes serious damage.

Tests have shown that the effectiveness of arsenate of lead when employed against the budworm varies with the carrier with which it is used, as indicated in Table 2.

TABLE 2.—*Relative efficiency against the tobacco budworm of arsenate of lead with different carriers.*

Poison.	Experiment No.	Budworm injury.
		Per cent.
Arsenate of lead, 1 pound; corn meal, 75 pounds	1	0.79
Arsenate of lead, 1 pound; gypsum, 25 pounds	2	3.00
Arsenate of lead, 1 pound; fuller's earth, 16 pounds	3	2.50

In experiment No. 1 arsenate of lead was used at the rate of 1 pound to 75 pounds of corn meal and only 0.79 per cent of leaves showed injury. In experiment No. 2 the arsenate of lead was used three times as strong as in experiment No. 1 (1 pound to 25 pounds), but with gypsum as a carrier. Three per cent of the leaves were injured—nearly four times as many as in experiment No. 1. In experiment No. 3 the arsenate of lead was used nearly five times as strong as in experiment No. 1, yet the leaf injury amounted to 2.5 per cent—more than three times that in experiment No. 1. These experiments indicate that of the three carriers corn meal is preferable in budworm control.

GENERAL RECOMMENDATIONS.

At the end of the growing season tobacco plants from which the marketable leaves have been removed are often allowed to remain standing in the fields. These provide breeding places for the budworm as well as other insect pests. As soon as possible after harvesting is completed plants should be either cut or pulled up and then plowed under.

Where tobacco is grown under cheesecloth, preventive measures against budworm attack may be practiced with a great deal of success. In such cases care should be taken to patch all holes in the cloth. Since it is necessary to provide openings in these shades through which workmen with farm animals and implements may come and go, gates covered with cheesecloth should be provided, and kept closed as much as possible so as to exclude the moths, or adults, of the budworm.

Plants frequently are left growing within and around old seed beds. These invariably are infested and contribute considerably to the abundance of moths which deposit eggs on plants within the fields. Plants about the seed bed should be destroyed, therefore, as soon as the seed bed is abandoned.

Seed beds should always be covered and walled in with cloth so as to prevent the entrance of moths. In this way the number of eggs introduced into the fields on the plants will be held to a minimum.

Because of the nature of attack of this tobacco pest, much care is necessary in direct-control practices. A slight delay in making poison applications often results in great damage to the crop.

The necessity of applying the mixture directly to the leaves of the bud can not be too greatly emphasized. The effects of careless manipulation may be almost as bad as if no control measures were attempted.

Planters should keep these points clearly in mind, because the difference between a valuable tobacco crop and one of less than ordinary quality is often dependent upon the care with which budworm control is practiced.

Direct control in Florida and Georgia should begin as soon as possible after the plants have become established in the field. Applications of the poison mixture should be made in the buds from then until the plants have been topped. It is of special importance to emphasize the necessity of beginning the applications of the poison mixture as soon as the plants are set in the field. A delay in starting this work may give time for the eggs that are introduced from the seed beds to hatch, and for the young larvæ (young budworms) to reach the bud and do considerable damage. For the best results the buds must be treated twice a week until topping has been completed.

The best mixture which has been employed in experiments under actual field conditions is 1 pound of arsenate of lead and 75 pounds of corn meal (approximately 6 heaping teaspoonfuls to 1 peck of corn meal). Bolted or sifted meal is preferable to the unsifted product. In the preparation of this mixture care should be taken to obtain an even distribution of the poison throughout the corn meal. For this purpose mechanical mixers have been employed where large quantities are necessary. These, however, are not essential, for with a little care the mixture can be prepared quite as well by hand.

Caution.—Calcium arsenate should *not* be used as a substitute for arsenate of lead in the budworm poison mixture.

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THE RED SPIDER ON COTTON AND HOW TO CONTROL IT

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Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

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OWING to the minuteness of red spiders and to the fact that they live chiefly on the underside of the leaves which they attack, they are comparatively little known to the layman.

Their infestation of cotton, cultivated violet, garden bean, dahlia, sweet pea, and hollyhock gives much trouble to farmers, gardeners, and housewives, but the result of their work frequently is confused with " rusts."

The red spider is known to feed on 183 kinds of plants, of which 55 per cent are cultivated and 45 per cent are native wild species.

To prevent the spread of red spiders by eliminating weeds about fields and by destroying the pest on dooryard plants has been found possible, and as a control measure is of first importance.

By pulling and destroying the first few plants which show infestation the pest often may be stamped out.

Four different contact sprays have been found to be entirely satisfactory for use against the red spider on cotton. These are potassium sulphid, lime-sulphur, kerosene emulsion, and flour-paste solution, and the dilution for each spray is given on page 13. *Prevention is of vital importance, however, owing to the heavy expenditure of time, labor, and material which is necessary to control the pest when it is abundant in fields.*

THE RED SPIDER[1] ON COTTON AND HOW TO CONTROL IT.

CONTENTS.

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 causes sericus injury to cotton in the 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 drooping 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 infestion spreads upward until often only the bare stalk and one or two terminal leaves remain. (See figs. 3, 4, and 5.) Such plants almost always die.

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

[1] *Tetranychus telarius* L., generally known as *T. bimaculatus* Harvey, and in some publications as *T. gloveri* Bks.; order Acarina, family Tetranychidae.

NOTE.—This bulletin is a revision of Farmers' Bulletin 735.

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, to be devoured in feeding, but must be attacked by sprays which kill by contact.

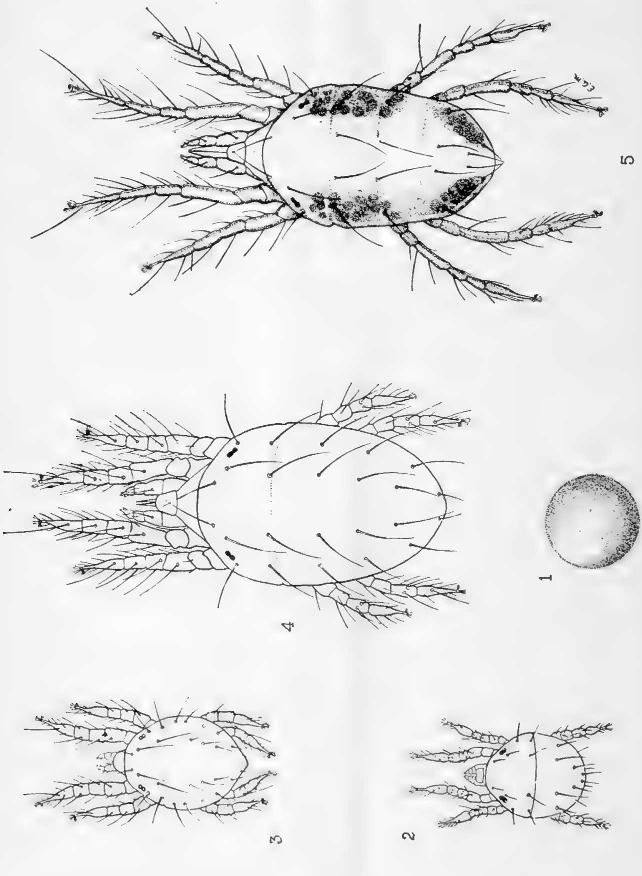

FIG. 1.—The common red spider (*Tetranychus telarius*): *1*, The egg; *2*, the newly hatched larva; *3*, the recently molted protonymph; *4*, the mature deutonymph just prior to the final molt; *5*, the adult female. Highly magnified. (McGregor and McDonough.)

DISTRIBUTION IN THE SOUTHEAST.

The common red spider is very generally distributed in the United States. The map (fig. 2), which contains 297 records of occurrence in 34 States, shows the distribution of the majority of reported cases.

The majority of the occurrences in the Southeast are confined to a zone the outer margin of which lies from 60 to 80 miles from the coast, while the inner margin is from 200 miles (along the Atlantic coast) to 275 miles (along the Gulf coast) inland (fig. 2).

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. 6.) The area finally affected, semicircular in shape, comprised 13 acres, and within

FIG. 2.—Distribution of the common red spider. Dots represent specific occurrences; dotted line incloses the zone of heaviest occurrence in the Southeast. (McGregor and McDonough.)

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 one season (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 1912 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.

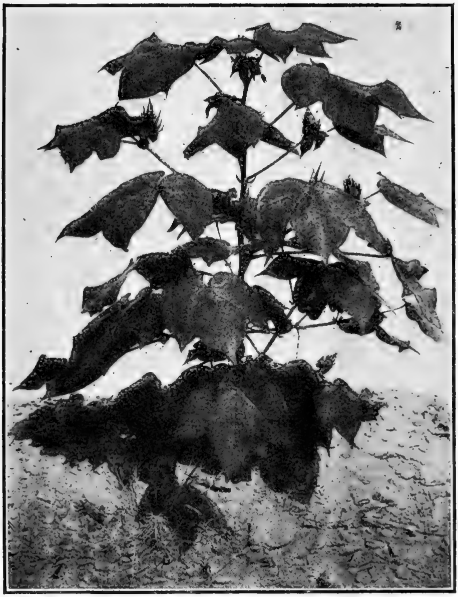

FIG. 3.—An uninfested cotton plant, growing in same field shown in figure 6, but just beyond the boundary of infestation by the red spider.

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.

SEASONAL HISTORY AND HABITS.

FIG. 4.—Cotton plant in an early stage of infestation by the red spider. Many leaves are discolored and some of the lower ones have dropped.

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.

The great majority of red spiders pass the winter on wild plants, and since these plants support the mite during the time of year when it is most difficult for the pest to survive, it is clear that they 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 return 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. 5.—Cotton plant in well advanced stage of infestation by the red spider. Nearly all leaves, squares, and bolls have been shed.

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, more than 300,000,000 offspring. In the meantime most weeds and garden plants that stand in the path of the red spider's advance have 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 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 again is shed and the secondary nymph appears. The 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, in 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 secondary 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 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. Usually the eggs are 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 a day, 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 there is a reduction 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 6 eggs a day will, upon the occurrence of a hot day, suddenly increase the number, often to 15 or 20 eggs a 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 11) 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. 7), or from a series of migrations covering considerable distances.

FIG. 6.—A severe example of red-spider work in a cotton field. Nearly all plants in the foreground are in the condition shown in figure 5. The source in this case was certain pokeweed stalks growing in the weed border seen in the upper right-hand corner of the figure.

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 usually is 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 because of 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 travel directly from plant to plant by means of the interweaving branches.

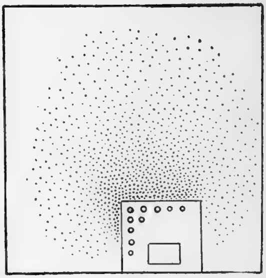

FIG. 7.—Diagram showing how violets growing in dooryard give rise to red-spider infestation in adjoining cotton field. The infestation is most severe near the yard. This diagram is typical of many cases.

PLANTS ATTACKED.

The red spider has been found breeding on 183 kinds of plants, of which 55 per cent are cultivated and 45 per cent are native wild species. Weeds, ornamental plants, and garden and field crops are included. 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 known to be attacked by 31 predacious 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. These predatory enemies, in turn, are known to be attacked by 75 species of predatory enemies and parasites.

REMEDIES FOR THE RED SPIDER.

PREVENTIVE MEASURES.

The red-spider problem must be solved 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 the red spider. Many cases of cotton infestation can be traced to near-by dooryards. The beds of violets and other plants should be sprayed thoroughly as soon as they show signs of infestation. The most satisfactory procedure, where violets are concerned, is to remove or destroy them.

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. 8.) 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.

FIG. 8.—Portable barrel pump for application of herbicide to weed borders.

SPACING.

Some have stated 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 are few 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 using this method it usually is 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 usually is 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 infested area 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 be resorted to in extreme cases only, 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);

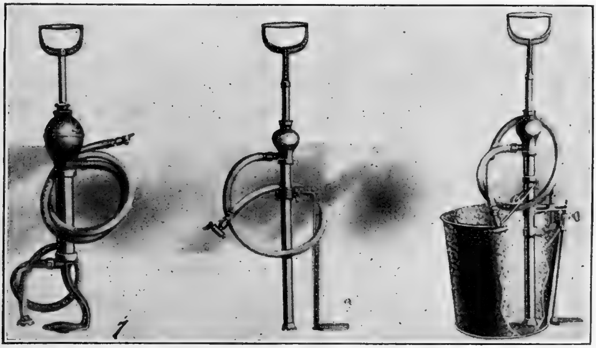

FIG. 9.—Bucket spray pump. (Quaintance.)

(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. 9) and knapsack pump (fig. 10) 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 economical 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 11 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 day is readily obtainable with these devices.

FIG. 10.—Knapsack sprayer. (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


FIG. 11.—Ideal spraying outfit for treatment of considerable red-spider infestation.

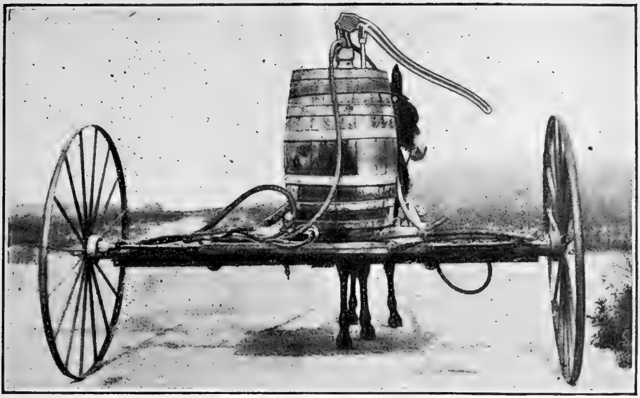

FIG. 12.—Barrel pump with double lead of hose mounted on dismantled hayrake. Same outfit as shown in figure 11. (McGregor and McDonough.)

"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 with a contact insecticide; (3) maintaining a finely pulverized surface soil; (4) destruction of early infested plants on large areas of heavy infestation by plowing up and burning; and finally, if the infestation is more or less general, (5) spraying the cotton plants with one of the following contact insecticides: Potassium sulphid, lime-sulphur, kerosene emulsion, or a flour-paste solution.

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE RELATING TO INSECTS INJURIOUS TO COTTON OTHER THAN THE BOLL WEEVIL.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

The Bollworm or Corn Earworm. (Farmers' Bulletin 872.)
The Fall Army Worm, or "Grass Worm," and its Control. (Farmers' Bulletin 752.)
The Argentine Ant: Distribution and Control in the United States. (Department Bulletin 377.)
The Red Spider on Cotton. (Department Bulletin 416.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE.

Miscellaneous Cotton Insects in Texas. (Farmers' Bulletin 223.) Price, 5 cents.
Two Destructive Texas Ants. (Entomology Circular 148.) 1912. Price, 5 cents.
Cotton Stainer. (Entomology Circular 149.) 1912. Price, 5 cents.
Cotton Worm or Cotton Caterpillar. (Entomology Circular 153.) 1912. Price, 5 cents.
Report on Miscellaneous Cotton Insects in Texas. (Entomology Bulletin 57.) 1906. Price, 5 cents.
Cotton Stalk-borer. (Entomology Bulletin 63, pt. VII.) 1907. Price, 5 cents.
Mexican Conchuela in Western Texas in 1905. (Entomology Bulletin 64, pt. I.) 1907. Price, 5 cents.
Notes on Economic Importance of Sowbugs. (Entomology Bulletin 64, pt. II.) 1907. Price, 5 cents.
Plant-bugs Injurious to Cotton Bolls. (Entomology Bulletin 86.) 1910. Price, 20 cents.
Argentine Ant. (Entomology Bulletin 122.) 1913. Price, 25 cents.

HOW TO DETECT OUTBREAKS OF INSECTS AND SAVE THE GRAIN CROPS

W. R. WALTON

Entomologist in Charge of Cereal and Forage Insect Investigations

A billbug, much enlarged

FARMERS' BULLETIN 835

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C. June, 1917

Additional copies of this bulletin may be obtained free from the Division of Publications, U. S. Department of Agriculture

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MAXIMUM YIELDS of grain must be produced not only during the present year but for several years to come. The present international situation renders this imperative. Insects are responsible for great reductions in grain crops annually, but such losses are largely preventable. The injuries caused by insects often remain unnoticed except where their work is very conspicuous.

Therefore, WATCH THE CROPS CAREFULLY FOR EVIDENCES OF INSECT INJURY AND APPLY REMEDIES PROMPTLY. This bulletin will tell you how to fight the Hessian fly, chinch bug, army worm, cutworms, grasshoppers, white grubs, billbugs, corn root-aphis, and wireworms.

Keep in close touch with your county agricultural agent, State experiment station, or Federal entomological station. Report all serious insect outbreaks to these officials and seek their expert advice in all cases of doubt regarding treatment for, or identity of, insect pests. Have a supply of insecticides and a practical spraying outfit on hand at all times. WATCH YOUR CROPS.

HOW TO DETECT OUTBREAKS OF INSECTS AND SAVE THE GRAIN CROPS.

CONTENTS.

A GREAT portion of the annual loss to the grain crop due to insect injuries can be avoided by vigilance and vigorous action on the part of the grain growers. Insect outbreaks frequently originate within limited areas, and when this is the case it often is possible to stamp them out before any great damage has occurred. In other instances the outbreaks are of general origin, and then community action is essential in order that the inroads of the pest may be overcome. The most serious insect enemies of cereal crops, such as the Hessian fly, the chinch bug, and white grubs, belong to the latter class. In the case of these and other widely distributed foes of the grains no means of stopping their ravages will be fully successful until community action can be secured in adopting the methods of combat at present advocated by entomologists.

Fall plowing, doubtless, is the most universally beneficial practice for the control of the insect pests of cereal crops, and this measure should be adopted except where it is rendered impossible by local agricultural conditions. Corn never should be planted on freshly broken sod land, because this practice is almost certain to expose the crop to the ravages of cutworms, wireworms, and white grubs. Crops belonging to the bean family, such as cowpeas, soy beans, clover, alfalfa, etc., may be interposed safely between sod and grain and especially between sod and corn, in order that injury to the grain crops by these pests may be avoided.

HESSIAN FLY.[1]

The Hessian fly, found throughout almost the entire winter-wheat region (fig. 1), is a minute, mosquitolike fly which lays its eggs upon

[1] *Phytophaga destructor* Say.

the leaves of wheat. These eggs hatch into little maggots which crawl down into the leaf sheaths. There they live upon the plant's sap, which they obtain by gnawing into the soft portions of the stem. Usually two, but sometimes three or more, generations of the insect occur during a year.

One main generation of flies (see fig. 2) appears in the fall, the large proportion of the maggots becoming full-grown before the severe weather of winter arrives, when they change into brown seed-like forms known as "flaxseeds." These may be found within the leaf sheaths in young wheat plants, usually at or beneath the surface of the soil. These overwintering "flaxseeds" produce the spring generation of flies. These, in turn, lay eggs from which hatch maggots that cause great injury to wheat, noticed about harvest time, when the straws break off and the crop is said to be "straw fallen."

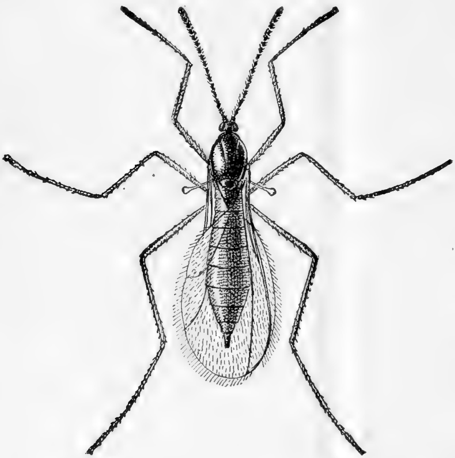

FIG. 1.—The Hessian fly (*Phytophaga destructor*): Adult female. Much enlarged.

After the Hessian fly has once thoroughly infested the crop of wheat there is no known means of saving it, and the only known means of preventing damage from the fly is to keep it out of the wheat.

For this reason the young wheat should be examined thoroughly in order that the presence of the brown "flaxseeds" may be detected late in winter or very early in the spring, and if these are found to be present in large numbers it will pay to plow down the wheat at once and prepare to plant corn, oats, or some other crop in its place. In this way the fertilizing value of the green crop will be retained in the soil and it will still be possible to secure a crop of grain or vegetables from the field during the current year.

The remedies for the Hessian fly are entirely preventive and are as follows:

(1) Immediately after harvest, or as soon thereafter as practicable, plow the wheat stubble down deeply, at least 5 inches deep if possible, in order to destroy the maggots and "flaxseeds" which may remain in it. This is for the protection of future crops.

(2) Pay great attention to the preparation of the seed bed for the wheat by plowing early and working and packing the soil thoroughly in order to eliminate lumps and clods, thus producing a finely pulverized, compact, and moisture-conserving bed for the seed.

FIG. 2.—Diagram showing seasonal development of the Hessian fly.

(3) *Destroy all volunteer wheat* by plowing or disking, as such wheat serves to carry the flies over from fall to spring, even though most of the fields of wheat have been treated properly and contain no flies. *One field in which volunteer wheat is allowed to remain may*

breed enough Hessian flies to infest a whole neighborhood where the grain is otherwise free from the fly.

(4) Take care that the sowing of wheat in the fall is delayed until the fly-free date. Information regarding this date can be obtained by applying to your county agricultural agent, your State experiment station, or to the nearest entomological field station of the United States Department of Agriculture.

(5) Practice a good rotation of crops wherever possible.

(6) Secure the cooperation of the entire community in following the methods mentioned. This is absolutely essential in order that satisfactory results may be obtained.[1]

CHINCH BUG.[2]

Next to the Hessian fly the chinch bug doubtless is the most destructive pest affecting cereal crops. It does greatest damage to corn. The adult or full-grown bug (fig. 3) is black and about one-eighth of an inch in length, and usually bears conspicuous white wings folded over its back. The young ones are bright red and wingless. The old bugs live over the winter hidden among clumps of wild grasses, especially those known as the "broom sedges," which grow abundantly in uncultivated places throughout the greater portion of the main wheat belt of the United States. *It is most important, therefore, either to prevent these grasses from accumulating in waste or uncultivated fields or else to burn them over while dry during the late fall or early in the spring, before the bugs have left the dry grasses and become distributed over cultivated crops.*

FIG. 3.—The chinch bug (*Blissus leucopterus*): Adult, long-winged form. Much enlarged.

It is the usual habit of the chinch bug first to attack fields of wheat, rye, or barley, and its presence often is unnoticed because the injuries inflicted upon these crops are obscure or of no apparent importance. About harvest time the bugs leave the small grains and crawl over the surface of the ground to the nearest fields of corn (fig. 4), where they begin at once to wreak severe injury. *It is, therefore, very important that the presence of the bugs be detected before they have reached the corn and if possible before they have started to migrate from the small grains to the cornfields.*

Cornfields may be protected and the migrating bugs trapped about the time of wheat harvest, as follows: Plow a deep furrow along

[1] Further information regarding this pest is contained in Farmers' Bulletin 640, which may be secured free of charge upon application to the Secretary of Agriculture, Washington, D. C.

[2] *Blissus leucopterus* Say.

the edge of the field, running the land side of the plow toward the field to be protected. In dry weather the sides of the furrow can be made so smooth and the sides so steep that the bugs will find it easier to crawl along the bottom than to climb up the sides. Circular holes from 30 to 40 feet apart, made with a post-hole digger, then may be dug in the bottom of the trench. Into these holes the bugs will fall in large numbers, and here they may be killed easily by sprinkling kerosene oil over them. A log dragged back and forth

FIG. 4.—Corn plant infested with chinch bugs. When the bugs are as numerous as this on the corn it can not be saved. *Do not let them reach the corn.*

along the furrow is useful in keeping the bottom and sides in good condition during dry weather. In wet weather a line of liquid tar or crude petroleum, which the bugs will not cross, may be maintained in the furrow bottom.

Spraying for chinch bugs has not proved successful except on a small scale and when conducted by an expert, the difficulty being that the substances which kill the bug are almost sure to kill the corn also. *The thing to do is to discover the bugs before they reach the corn and keep them out of it by the methods described above.*

In case the bugs have reached only the first few rows of corn, however, they may be killed by spraying with a solution of one of the commonly used commercial washing powders prepared as follows: Dissolve 1 pound of washing powder in 2 gallons of boiling water. This is to be used as a stock solution; when ready to spray, dilute by adding 2 gallons of cold water to 1 of the stock solution, and apply to the infested rows with an ordinary force pump and sprayer. In order to be effective the soap-powder solution must come into contact with the bugs.

SUMMARY OF CONTROL MEASURES FOR THE CHINCH BUG.

(1) Burn the dried grasses in which the chinch bug winters, either late in the fall or very early in the spring.

(2) Watch for the bugs in young wheat, rye, or barley.

(3) Prevent the bugs from traveling from the small grains to the corn by ditching, as described.[1]

ARMY WORM.[2]

Watchfulness is the key to success in cases of invasion by army worms (see fig. 5), which are the young of certain moths or millers that fly only at night. The eggs from which the army worms hatch are laid commonly on grasses or grasslike grains and the tiny caterpillars, upon hatching, feed for several days near the ground, hidden by overhanging grasses or grains and thus may escape notice until nearly full grown, by which time they have become widely distributed over the infested fields.

Upon the discovery of the pest in its younger stages depends very largely the possibility of stamping out infestations before serious injury to crops has occurred. Meadows therefore should be examined frequently during the spring and early summer months, particularly those planted to timothy, bluegrass, wheat, and especially millet, to discover the young worms. One 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 examined closely, in order that the presence of the small, greenish caterpillars may be discovered, and if these 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 parts 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 dis-

[1] Additional information regarding the chinch bug is contained in Farmers' Bulletin 657, which may be secured free of charge by application to the Secretary of Agriculture, Washington, D. C.

[2] *Cirphis unipuncta* Haw.

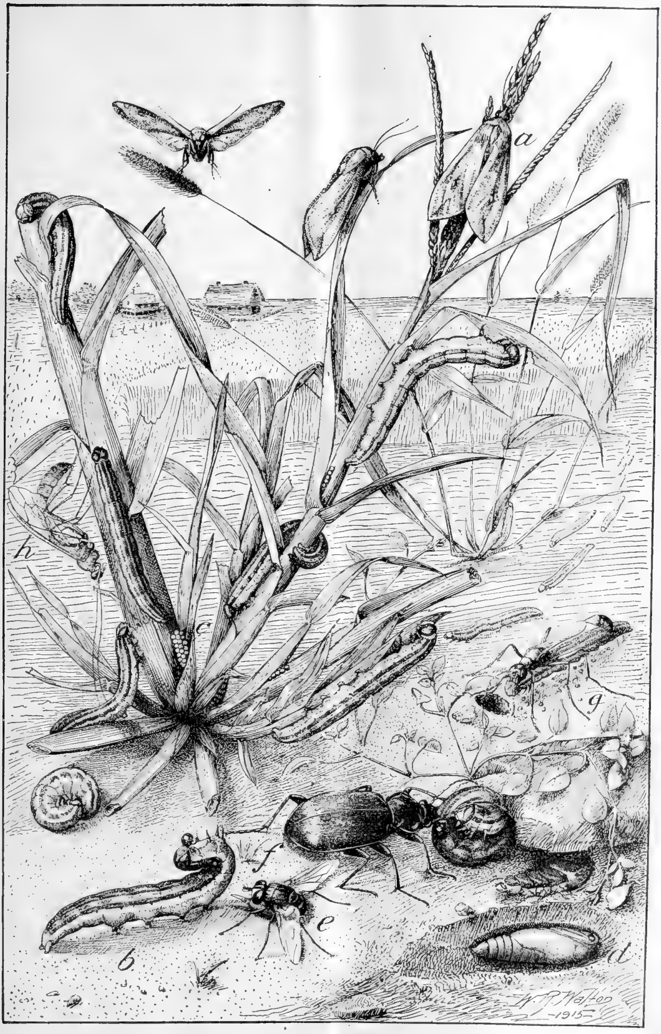

FIG. 5.—Stages and work of the true army worm (*Cirphis unipuncta*) and some of its insect enemies: *a*, Parent or moth; *b*, full-grown larva; *c*, eggs; *d*, pupa in soil; *e*, parasitic fly, *Winthemia quadripustulata*, laying its eggs on an army worm; *f*, a ground beetle, *Calosoma calidum*, preying 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.

tributed over a considerable area, this can be marked off by stakes and the crop sprayed heavily with a solution of Paris green at the rate of 1 pound to 50 gallons of water, or of arsenate of lead at the rate of 2 pounds of the paste or 1 pound of the powder 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 best by far 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 in any case and probably devastate other portions of the farm.

POISONED BAITS FOR THE ARMY WORM.

Poisoned baits have long been used as a means of destroying the numerous 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 powdered 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 molasses, and scatter the mixture broadcast in small pieces throughout the infested field. This poisoned bait may be used safely in alfalfa and cornfields where it is desired, if possible, to save the crop for forage.

MECHANICAL MEASURES AGAINST THE ARMY WORM.

In case the worms are not discovered until they have begun to travel in a mass, usually they can be destroyed by furrowing or ditching completely around the infested area (see fig. 6). The worms will fall into the ditches and can be killed easily by crushing them with a log dragged back and forth through the ditch or furrow. If shallow postholes 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 they may be destroyed by crushing or other means. If the subsoil be of such a nature that water penetrates it but slowly, the postholes may be filled partially with water, on the top of which a layer of coal oil or petroleum may be poured. The worms die almost immediately upon falling into such holes.

SUMMARY OF CONTROL MEASURES FOR THE ARMY WORM.

(1) Watch fields of growing grass and grain carefully, especially the meadows, during the spring and early summer months, to discover the army worms before they 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) Poison them by spraying crops not intended for forage with 1 pound of Paris green to 50 gallons of water, or with 2 pounds of powdered arsenate of lead to 50 gallons of water. In case the Paris green is used on tender plants, like corn, add 2 pounds of freshly slaked lime 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 already mentioned is strongly recommended.[1]

(3) 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.

FIG. 6.—Ditch prepared to entrap marching army worms. A log, dragged back and forth through the ditch, crushes the worms that have fallen into it.

CUTWORMS.

Numerous complaints of the ravages of cutworms (see fig. 7), especially in corn, are received by the department each season. Prompt action is necessary for controlling cutworms after their presence becomes noticeable in the spring, which usually is about the time the corn begins to sprout. *Since the crop may be destroyed by cutworms between the time an inquiry is sent to the department upon the appearance of the worms and the time a reply can be received, the importance of recognizing these insects and knowing how to control them is evident.*

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[1] Further information regarding this pest is contained in Farmers' Bulletin 731, which may be secured free of charge upon application to the Secretary of Agriculture, Washington, D. C.

Cutworm injury, which usually consists in the cutting off of the plants at or a little below the surface of the ground, almost invariably occurs in the spring, beginning as soon as the first plants sprout and continuing until late June or early July, by which time the worms are full grown. The worms feed at night and rest during the day beneath débris or in the soil from one-half to 1 inch below the surface, and since in most cases they resemble the soil closely in color the cause of the injury often is not apparent. However, if the soil surrounding the cut-off plant be examined carefully, the culprit probably will be found curled up beneath the surface as shown at *c* in figure 7.

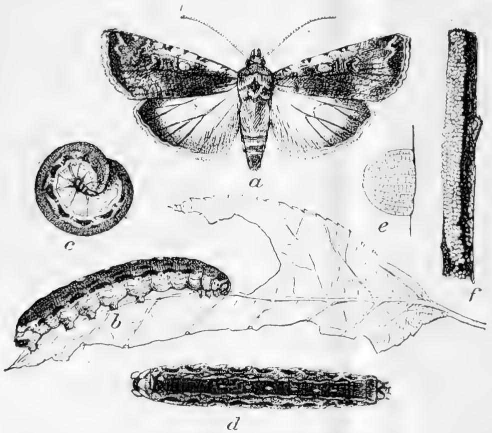

FIG. 7.—Variegated cutworm (*Peridroma margaritosa*): *a*, Moth; *b*, normal form of caterpillar, side view; *c*, same in curved position; *d*, dark form, view of back; *e*, greatly enlarged egg, seen from side; *f*, egg mass on twig.

SEASONAL HISTORY OF CUTWORMS.

The various species of cutworms are known under a number of names, such as 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 (see fig. 7, *e*, *f*), either in masses or singly, in fields covered with dense vegetation, and hence the eggs are to be found more often than elsewhere 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 an infested field is 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, suddenly being placed on "short rations," play 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 then 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.

If land that has been in grass for a considerable time and is likely to contain cutworms is to be planted to corn the following spring, it 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, allowed to follow the plow, is of great value.

When cutworms are found to be abundant on corn land, the use of the poisoned bait described on page 10 is recommended. In fields known to be infested, the distribution of this bait should be begun as soon as the corn appears above the ground, so that the cutworms may be eliminated as quickly as possible and the injured hills replanted promptly. 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 usually will be more effective if applied during the late afternoon and 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.[1]

GRASSHOPPERS.[2]

Grasshoppers are injuriously abundant in various parts of the United States every year. Their ravages, which occur chiefly on alfalfa and the grasses, can be prevented largely by cheap and practical means, especially where vigilance is exercised. These pests may be discovered in their young stages, when it is easy to control them

[1] Further information regarding these pests is contained in Farmers' Bulletin 739, which may be secured free of charge upon application to the Secretary of Agriculture, Washington, D. C.

[2] *Melanoplus* spp., etc.

by means of the poisoned baits described below. The more injurious kinds of grasshoppers nearly all live over the winter in the eggs which are placed in the ground by the old grasshoppers in late summer or early fall. The eggs hatch the following spring, usually during the months of May and June in the Northern States. *Every effort should be made to discover the young insects* (fig. 8) *before*

FIG. 8.—Young grasshoppers feeding on clover. In this stage they are easily killed by poisoning.

they have attained any considerable size, when the injury done by them is still very slight, and when they are wingless and easily killed by poisons or mechanical means.

POISONED BAITS FOR GRASSHOPPERS.

The most effective remedies yet discovered for grasshoppers are the following poisoned baits:

The mixture known as the poisoned-bran bait has proved 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. It is made up as follows: Wheat bran, 25 pounds; Paris green, 1 pound, or powdered arsenate of lead, 2 pounds; 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; water, 2 to 3 gallons. The bran and Paris green or arsenate of lead are thoroughly mixed while dry, the fruits are then finely chopped and added, and lastly the molasses and water are 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. 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 arsenate of lead, 2 pounds; finely chopped oranges or lemons, 6 to 8 fruits; water sufficient to make a moist but not sloppy mash. This bait must be mixed thoroughly 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.

In applying the poisoned bait in orchards, care must be taken to avoid distributing it close to the trees, because severe injury to fruit trees occasionally results from heavy applications of arsenicals.

Proper time of day 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. Apparently they are 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 in the early morning. *Farmers should not be discouraged if the grasshoppers do not drop dead immediately upon eating the poison, as it usually takes 24 hours or more for the full effect of the baits to become apparent.*[1]

WHITE GRUBS.[2]

White grubs (fig. 9) are the young of the common brown May beetles, or "June beetles," which begin to appear during the latter

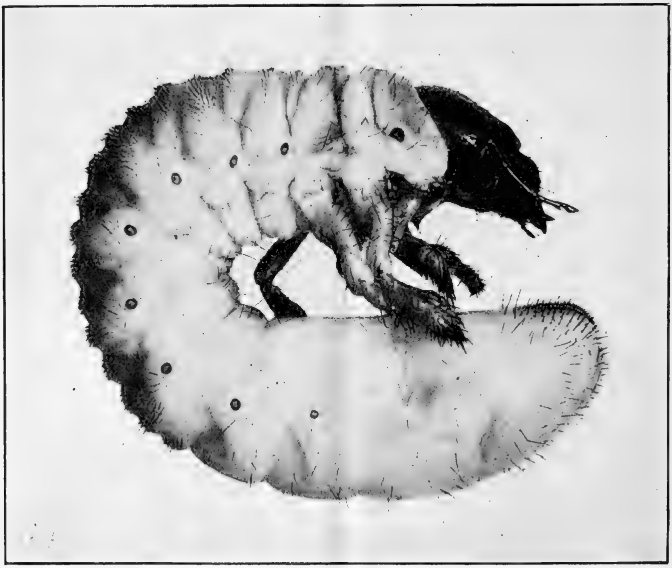

FIG. 9.—A full-grown white grub. Greatly enlarged.

part of April and continue to be seen in the evening throughout the month of May and even as late as June. These beetles lay their eggs in the ground, preferably in timothy grasslands. The little grubs, upon hatching, feed largely upon decayed vegetable matter in the soil and therefore are not usually detected at this time. On the approach of cold weather they burrow deeply into the soil, where they sleep or hibernate during the winter. When the next spring arrives

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[1] Further information regarding these pests is contained in Farmers' Bulletin 747, which may be secured free of charge upon application to the Secretary of Agriculture, Washington, D. C.

[2] *Lachnosterna* spp.

they approach the surface of the ground and begin to feed on the roots of grasses, corn, potatoes, strawberries, and seedling trees, especially conifers. They feed ravenously during this second year of their life and by fall are nearly full grown.

If land is found to be heavily infested with the grubs, it should be plowed thoroughly during the summer or early fall, the farm fowls being allowed to follow the plow in order that they may find and eat the grubs as these are brought to the surface. Chickens and other farm poultry are very fond of the insects. Hogs may be turned into such fields with profit, as it is their habit to root out and devour the grubs in great numbers.

On the approach of winter the nearly full-grown grubs once more descend deeply into the ground in order to hibernate until spring, when they come to the surface and feed for a few weeks. During the early summer months, usually in June, they go down deeply for the last time, changing to the resting stage or pupa during August, and then to the beetle in late September. The beetles remain in the ground all winter, coming up the following spring to feed upon the leaves of trees and lay their eggs in the soil for another generation. Thus it takes three years for most of the white grubs to complete their life cycle. Usually, therefore, they are especially abundant in any one region only one year in every three.

WHAT TO DO AT EACH STAGE OF WHITE-GRUB ATTACK.

When heavy flights of May beetles are noticed.—Use lantern traps during the beetles' flights. Spray trees with an arsenical, such as Paris green or arsenate of lead, to poison beetles feeding thereon. Plow grass and small grain land previous to October 1 to destroy young grubs recently hatched from eggs laid by May beetles.

When small grubs are abundant in the fall.—Plow thoroughly previous to October 1. Pasture hogs and allow chickens the run of fields when plowed. Seed such land to small grain or clover for the following year. Do not plant corn or potatoes on such land the following season.

When small grubs are abundant in the spring.—Seed such land to small grain or clover. Do not plant corn or wide-row crop in such land. Put corn, potatoes, field beans, etc., on ground which has been cleanly cultivated the preceding year. Pasture hogs on infested ground, and give chickens the run of fields when plowing and cultivating.

When large grubs are abundant in the fall or spring.—Plow infested land about October 1. Delay planting until the 15th or 20th of May, or a little later if practicable. Ground containing large grubs in spring should be plowed as soon after July 15 as practicable, as indicated below. Pasture hogs in infested fields wherever practicable.

When beetles or pupæ are in the ground in summer.—Plow thoroughly, so as to break clods, any time after July 15, but the sooner after that date the better. Pasture hogs in infested fields.[1]

BILLBUGS.[2]

The billbugs, snout-beetles, or "elephant bugs" (see fig. 10 and illustration on title page), as they are variously termed, are hard-shelled beetles which live normally in sedges, rushes, or the large wild grasses found growing in moist, low ground. Corn planted in river and creek bottoms or other low places, especially in the southern portions of the country, is liable to injury by billbugs. The grubs, or young, of these beetles live inside the stems or roots of plants, and their injuries to corn usually are caused by their eating out the central portion of the stalk, thereby stunting and seriously injuring the corn plants. (See fig. 11.) The adult beetles also injure the corn, for they puncture the growing point or "bud" of the plant.

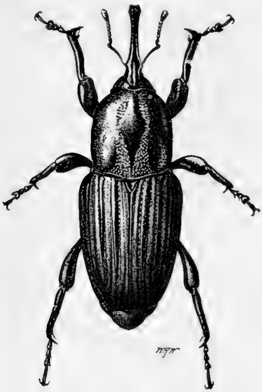

FIG. 10.—The maize billbug (*Sphenophorus maidis*): Adult, four times natural size.

REMEDIES FOR BILLBUGS.

Some kinds of billbugs are eliminated easily by rotation of crops. Corn should not be followed by corn in the Atlantic Coastal Plain region of the South, but may be alternated with cotton, on which the billbugs can not live. *Land infested with these insects should always be plowed in the late summer or early fall*, for thus the winter quarters of the bugs are broken up. The immediate destruction of all sedges, rushes, chufa, or large swamp-inhabiting grasses in land intended to be planted to corn is especially necessary, as these plants are the natural food of the billbugs, and the insects can not be eliminated unless this is done.

CORN ROOT-APHIS.[3]

The corn root-aphis (fig. 12) attacks the roots of corn throughout the States east of the Rocky Mountains, especially in those States

[1] Further information regarding these pests is contained in Farmers' Bulletin 543, which may be obtained free of charge upon application to the Secretary of Agriculture, Washington, D. C.

[2] *Sphenophorus* spp. The species illustrated on the title-page is *Sphenophorus aequalis* Gyll.

[3] *Aphis maidi-radicis* Forbes.

FIG. 11.—Corn plants showing effects of feeding of maize billbug in the field. Plant at left not attacked, the two at right attacked by larvæ.

within the main corn belt of the country, but also in the South Atlantic States. Since it passes almost its entire life underground, its presence frequently is not suspected. It is a small, stout, soft-

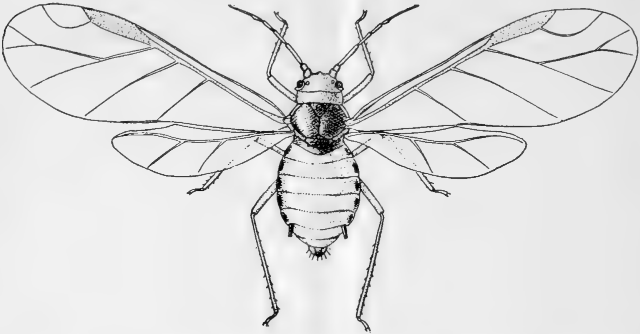

FIG. 12.—The corn root-aphis (*Aphis maidi-radicis*) : Winged, viviparous female. Greatly enlarged.

bodied, whitish-looking insect and may be discovered in infested fields by pulling up the unhealthy corn plant and closely examining the roots and surrounding soil. This kind of aphis depends entirely upon the services of a small brown ant, sometimes called the cornfield ant, in order to secure its food and the means of surviving the winter, and the presence of an unusual number of brown ants in cornfields may indicate an infestation of the corn root-aphis. The eggs of the insect are laid by a wingless female aphis (fig. 13) which develops only in the fall of the year. The ants carry the aphis eggs into their nests, caring for them all winter long, and in the spring when the eggs hatch the young aphids are carried out and placed in contact with the roots of certain wild plants such as smartweed. If corn is then planted in such infested places, the ants transfer the aphids to the roots of the corn plants, where they continue to live upon the sap, thereby robbing the corn of its nourishment and often causing a heavy loss to the crop.

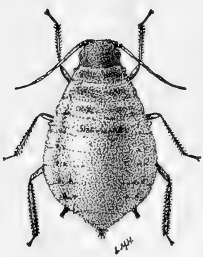

FIG. 13.—The corn root-aphis: Egg-laying female.

CULTURAL PRACTICES FOR THE CORN-ROOT APHIS.

Stir the soil thoroughly previous to planting. The object of this procedure is to disturb the ant colonies and scatter and kill the aphids so as to enable the plants to make a substantial growth before the ant and aphid colonies can become reestablished, and also to prevent the growth of weeds upon which the aphids live, making it necessary for the ants to carry the surviving aphids to new fields. If infested fields are to be replanted to corn, plow them to a depth of $6\frac{1}{2}$ or 7 inches in the spring after March 15. Follow this with three or four diskings to a depth of 4 or 5 inches with a 16 or 20 inch disk, the number of diskings and the intervals between them varying according to the length of the period between plowing and planting. When it is necessary to replant early injured corn, plow the field deeply and thoroughly and then give three or four deep diskings at intervals of two or three days. These practices necessarily involve additional labor, but they prevent root-aphis injury and also put the field in much better physical condition. Plowing in the fall before the ant colonies go below the plow line is sometimes as useful as spring plowing, but if warm weather follows, the ants may reconstruct their nests and reassemble the aphids so that replowing in spring will be necessary; but whether the field be plowed in the fall or the spring, the spring diskings are essential.

Early fall plowing, followed by frequent deep diskings in fields damaged by the root aphis that season, is a good practice from the standpoint of community control as well as for the personal benefit derived, because the plowing disturbs the ant colonies, kills many of the aphids, and destroys the weeds upon which they live, and disking prevents the recolonization of ants and prevents the growth of weeds, resulting in a significant reduction in the number of aphid eggs to carry the insect through the winter.

REPELLENTS FOR THE CORN-ROOT APHIS.

Where it is impossible to practice one of the foregoing measures, repellents may be used to advantage. The object is to repel the ants by the use of an odorous substance offensive to them, thus preventing them from colonizing the aphids on the corn roots or driving them from the treated field. These materials destroy neither the ants nor the aphids but tend to drive away the ants, the presence of which is essential to the life of the aphids. Oil of tansy, tincture of asafetida, oil of sassafras, anise oil, kerosene, and oil of lemon are useful for this purpose, one of these materials being mixed with a chemical fertilizer, such as bone meal, and applied by means of a planter equipped with a fertilizer attachment. They should not be applied directly to the seed, as such treatment may injure it, especially if the season be wet. One-fourth of a pound of oil of tansy should be diluted with 2 quarts of alcohol and 1 quart of water, 2 pints of asafetida should be diluted with $1\frac{1}{2}$ gallons of water, and either repellent thus diluted should be added to 100 pounds of bone meal, this amount being sufficient for an acre.

WIREWORMS.

Wireworms (see fig. 14) are especially destructive to seed corn in the ground and to the young corn and wheat plants. They work entirely underground and are among the most difficult to control of all the insect foes that afflict the farmer. Much may be done, however, to lessen their ravages by careful tillage, drainage, proper rotation of crops, etc., as will be explained.

Wireworms are the young of the common snapping beetles, or click beetles, and the worms are yellowish or brownish, highly polished and slippery to the touch. They move actively and disappear rapidly when brought to the surface by the plow or spade. The

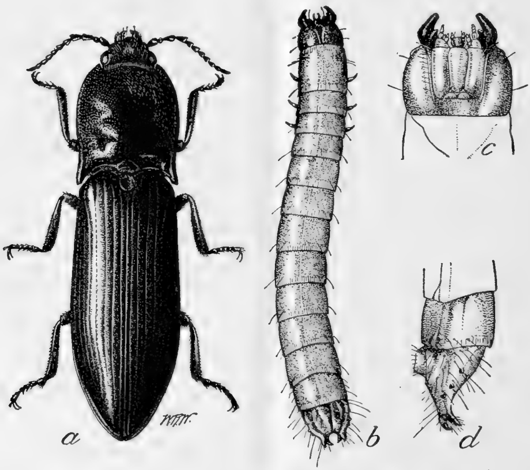

FIG. 14.—The dry-land wireworm (*Corymbites noxius*) : *a*, Adult ; *b*, larva ; *c*, under surface of head of larva ; *d*, side of last segment of larva. *a*, *b*, Enlarged ; *c*, *d*, more enlarged.

eggs are laid in the ground, usually in sod lands, where the young worms are hatched. It takes three years for most kinds of wireworms to get their full growth and to become beetles.

REMEDIES FOR WIREWORMS.

The most successful methods for the control of wireworms are cultural in nature, it having been found impossible, or at least impracticable, to poison them by any known means.

Where it is proposed to plant sod land to corn the following year, to prevent wireworm injury the land should be plowed immediately after the first hay cutting, usually early in July, and should be cultivated deeply during the remainder of the summer.

Land already in corn which is badly infested should be cultivated deeply, 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 tilled thoroughly before it is sown to wheat.

In regions where wheat is seeded down for hay, any treatment of infested fields is precluded. Where the wheat is not followed by seeding to other crops, the fields should be plowed as soon as the wheat is harvested. This kills the worms by destroying their food supply and preventing them from preparing suitable sleeping quarters for the winter.

A thorough preparation of corn land and a liberal use of barnyard manure or other fertilizer is recommended, and a vigorous stand may be produced sometimes in spite of the wireworms by such treatment. Wherever practicable the interposing of crops not severely attacked by wireworms, such as field peas or buckwheat, between sod and corn tends materially to reduce the number of wireworms in the soil.

Some kinds of wireworms live only in badly drained land, and for this reason thorough tile draining of such fields is often very beneficial, especially where the general condition of the fields is improved by proper applications of lime and thorough cultivation.

In the Northwest and northern Middle West the dry-land wireworm (fig. 14) sometimes is very injurious. The following methods have been found to be valuable in the elimination of this pest: (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 mulch and keep down the 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.[1]

Do not plant grain, and especially corn, on freshly broken sod land if this can be avoided. To do so exposes it to almost certain injury by wireworms, cutworms, and white grubs. Plant such land first to soy beans, cowpeas, clover, alfalfa, or buckwheat, afterwards rotating to grain. The growing of any one kind of grain on the same land continuously is sure to result in damage from insect pests, and is bad agricultural practice. Adopt a good system of crop rotation suitable to your particular region. If you do not know the most approved system of rotation for your locality, ask your county agricultural agent or State experiment station for advice.

[1] Farmers' Bulletin 725 contains additional information on wireworms and will be mailed free of charge on application to the Secretary of Agriculture, Washington, D. C.

POINTS TO REMEMBER.

(1) Watch the grain crops carefully for the earliest indications of insect outbreaks. Make a daily survey of the fields during the most active growing season, if possible.

(2) If an outbreak of any insect foe is discovered, apply promptly the remedies recommended in the foregoing pages.

(3) If in doubt as to the identity of the pest, promptly send a specimen, inclosed in a tight tin box, to your county agricultural agent, State experiment station, or nearest Federal entomological field station, accompanied by a request for information regarding it.

(4) Keep on hand at least a small supply of the standard insecticide preparations, such as Paris green, lime, and arsenate of lead. Very often the delay caused by the fact that these preparations are not immediately available is fatal to the crop attacked.

(5) Report serious outbreaks of insects to one of the authorities mentioned above. Federal entomological field stations charged with the investigation of cereal and forage insects are located at the following places:

Arizona—Tempe.
California—Martinez.
Indiana—West Lafayette.
Iowa—Sioux City.
Kansas—Wellington.
Maryland—Hagerstown.
Missouri—Charleston.
Ohio—Wakeman.
Oregon—Forest Grove.
Pennsylvania—Carlisle.
South Carolina—Columbia.
Tennessee—Knoxville.
Texas—San Antonio.
Utah—Salt Lake City.
Virginia—Charlottesville.

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THE ASPARAGUS BEETLES AND THEIR CONTROL

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FARMERS' BULLETIN 837

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C. August, 1917

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ASPARAGUS GROWERS in large sections of the United States now have to protect their crop against the attacks of the adults and young of two species of beetles introduced originally from Europe. These insects feed on the young and tender asparagus shoots and render them worthless for the market. Later broods devour the foliage and frequently kill the plants.

This bulletin gives brief descriptions of the various stages of these pests, tells how they live and work, and gives suggestions for controlling them. Of remedial measures the best for general use is shown to be spraying with arsenate of lead, directions for the preparation and application of which are given on pages 10–11.

THE ASPARAGUS BEETLES AND THEIR CONTROL.

CONTENTS.

ALTHOUGH introduced into this country from Europe by the early settlers, asparagus is believed to have been cultivated here for two centuries before it was troubled by insects. Several species of native American insects, it is true, feed upon this plant, but none, so far as we know, has become sufficiently attached to it to cause serious injury. Few of our edible plants, indeed, down to the time of the Civil War have enjoyed such immunity from insect ravages.

In the Old World, however, two insects called asparagus beetles have been known as important enemies of this crop since early times. One of these, known as the common asparagus beetle, was introduced into Greater New York about 1860, while the other, the twelve-spotted asparagus beetle, sometimes called the red asparagus beetle, to distinguish it from the blue or common species, was first discovered in this country on asparagus in 1881 near Baltimore, Md. Both of these are now firmly established and widely distributed in this country and require special measures for their control.

THE COMMON ASPARAGUS BEETLE.[1]

GENERAL APPEARANCE OF BEETLE AND CHARACTER OF INJURY TO PLANTS.

The adult of the common asparagus beetle is a beautiful insect, slender and graceful, blue black with red thorax and lemon-yellow and dark-blue wing-covers having a reddish border. A common form about the District of Columbia is illustrated in figure 1, *a*. Farther north the prevailing form is darker, the lighter coloring sometimes showing only as a reddish border and six small submarginal

[1] *Crioceris asparagi* L.; order Coleoptera, family Chrysomelidae.

yellow spots. (Fig. 2, *a*.) An extreme, light form, not uncommon in the southern range of the insect, is shown for comparison in figure 2, *b*. The length of the body is a trifle less than one-fourth inch. The full-grown larva, or grub (fig. 1, *d*), is dark gray or olive, sometimes lighter but not infrequently very dark. Its head and legs are shining black and its body is soft and fleshy and much wrinkled. The pupa, or resting stage, shown in figure 1, *e*, is yellowish.

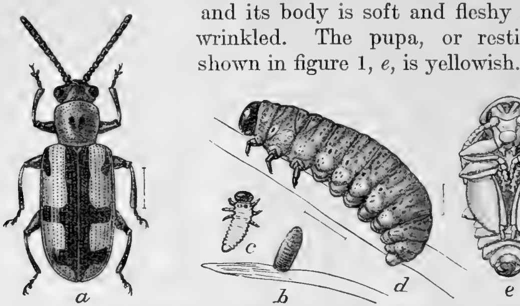

FIG. 1.—The common asparagus beetle: *a*, Beetle; *b*, egg; *c*, newly hatched larva; *d*, full-grown larva; *e*, pupa. All enlarged.

Injury by this insect is due to the work of both adults and larvæ, or "slugs," to the tender shoots, which they render unfit for market early in the season. Later they destroy by defoliation the high-grown plants, particularly seedlings, the roots of which become weakened when their tops are devoured. The larvæ are sometimes so abundant that the black molasseslike fluid which exudes from their mouths soils the hands of those engaged in bunching the stalks for market, and the eggs are sometimes laid upon the stalks in such numbers that the latter are rendered unsightly and even slippery by their presence. Larvæ, as well as beetles, attack the tenderer portions of the plants, but the beetles gnaw the epidermis, or rind, of the stems, seemingly with equal relish. The beetles are also accused of gnawing young shoots beneath the surface, causing them to become woody and crooked in growth. (See illustration on title-page.)

FIG. 2.—The common asparagus beetle: *a*, Dark form of beetle; *b*, light form. Enlarged.

In some localities it is in the establishment of new beds that the greatest trouble and expense are incurred. The plants must grow a year as seedlings and two more in the beds before being cut for table use, and during these three years they are exposed to the attacks of this insect.

DISTRIBUTION AND MEANS OF SPREAD.

The common asparagus beetle was introduced at Astoria, near New York City, about 1856. From there it soon spread to the asparagus farms in Queens County, N. Y., and by 1862 was reported to have occasioned the destruction of more than one-third of the crops in certain localities, the loss being estimated at $50,000.

To date the common asparagus beetle has been reported in 19 States and the District of Columbia and in several localities in Canada. Its known distribution now extends from Toronto, Canada, through New York and New England, except Maine, to southern North Carolina and westward to the border line between Illinois

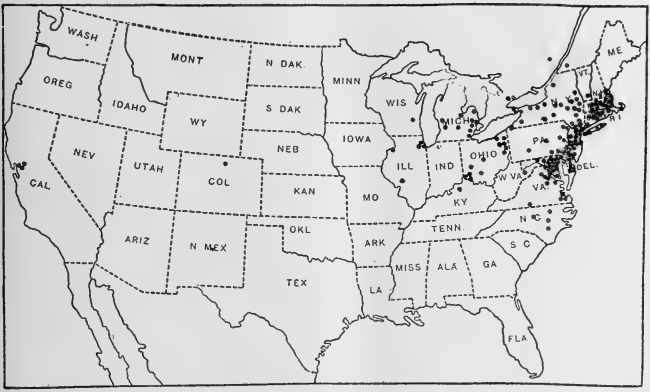

FIG. 3.—Map showing distribution of the common asparagus beetle in the United States and Canada as recorded up to the year 1917.

and Iowa, and in addition it has been reported from one locality, Boulder, in Colorado, and three in California. (See fig. 3.) Undoubtedly many localities in addition to those shown on the map will be added in time, for it is rather certain that the insect occurs elsewhere in Canada and in some of our States, such as Maine, Iowa, Wisconsin, and Illinois. This species appeared at Bouldin Island, Cal., in 1904, but disappeared subsequently, probably owing to the fact that the island had been flooded, causing the extermination of the pest.

The common asparagus beetle has been widely disseminated mainly by what are termed "commercial jumps," either through the presence of hibernating beetles and pupæ in shipments of propagating roots or by the accidental carriage of the beetles on railroad trains or boats.

The natural spread of the insect has been mainly by the flight of the beetles. Undoubtedly, also, the beetles have been carried from place to place along watercourses by the current and by the rising and falling of the tide. Until recently this insect has not spread far from the seacoast and the larger rivers near the coast. As is well known, asparagus was originally a salt water plant, and has escaped from cultivation and grows most luxuriantly near bodies of water, and it is upon wild asparagus plants that this insect first makes its appearance in new localities.

HABITS AND DEVELOPMENT.

The common asparagus beetle passes the winter in the adult state under convenient shelter, such as piles of rubbish, sticks, or stones, or under the loose bark of trees and fence posts. Toward the end of April or in May, according to locality, at about the season for cutting the asparagus for market, the beetles issue from their hibernating quarters and lay eggs for the first brood.

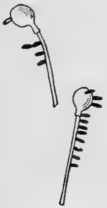
FIG. 4.—Eggs of common asparagus beetle on asparagus buds. Somewhat enlarged.

The egg is very large in proportion to the beetle, being nearly a sixteenth of an inch in length, and of the elongated-oval form illustrated at *b*, figure 1. It is nearly three times as long as wide and of a dark-brown color. The eggs are deposited endwise upon the stem or foliage and, in early spring, on the developing stalks, usually in rows of 2 to 7 or more. (Fig. 4.)

In from 3 to 8 days the eggs hatch, the young larvæ, commonly called "grubs," "worms," or "slugs," presenting the appearance indicated in figure 1, *c*. The head of the newly-hatched larva is large, black, and beadlike; its body is lead gray, and its three pairs of legs black. It begins to feed at once and in from 10 days to a fortnight attains full size, appearing as in figure 1, *d*. As previously stated, it is soft and fleshy, much wrinkled, and of a dark gray or olive color, sometimes light, but not infrequently very dark. The head is shining black, as are also the 6 legs. Each segment is provided with a pair of footlike tubercles which, with the anal prolegs, or false hind legs, assist it in crawling and in clinging to the plant. The mature larva enters the earth, and here, within a little rounded, dirt-covered cocoon formed by it, changes to a yellowish pupa (fig. 1, *e*). In 5 to 8 or more days this transforms to the adult beetle, which in a short time issues from the ground.

THE LIFE CYCLE.

The life cycle, or the time from the laying of the egg to the emergence of the adult, or beetle, covers about 30 days on Long Island, N. Y., but this period will be shorter in the hotter part of the season than in the cooler days of May and June.

During a hot period at Washington, D. C., eggs that were laid on August 5 hatched on the 8th, or in 3 days. A larva that transformed to pupa on August 4 became adult August 9, or in 5 days. Allowing 10 or 12 days as a minimum period for the larva stage, 2 days for the larva to enter the ground and form its cocoon, and 2 or 3 days more for the beetle to mature and leave the earth, the insect is again ready to attack its food plant and to continue the reproduction of its kind in about 4 weeks from the time that the egg is laid.[1] This may be fairly taken to represent the minimum midsummer life-cycle period of the species in the District of Columbia and southward, since the insect does not thrive in the summer season of tidewater Virginia. In the colder climate of New England, and elsewhere in spring and autumn weather, the development from egg to beetle will require from 4 to perhaps 7 weeks.

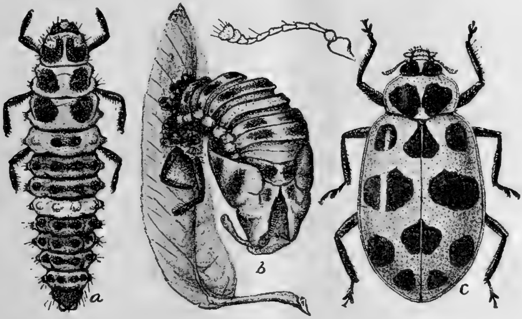

FIG. 5.—The spotted ladybird, an enemy of the common asparagus beetle: *a*, Larva; *b*, empty skin of pupa; *c*, adult with more enlarged antenna above. Much enlarged.

The hibernating beetles appear in the latitude of the District of Columbia as early as April and beetles of a later brood have been observed in abundance in October, as far north as northern Connecticut. In its northern range usually at least two generations are produced, and farther south there is a possibility of three or four generations each year.

NATURAL CHECKS.

Predacious insects of many kinds attack and devour the larvæ of the common asparagus beetle and assist very materially in preventing the beetle's increase. One of the most efficient is the spotted ladybird.[2] This beetle (fig. 5, *c*) is rose colored, with numerous black spots. The convergent ladybird,[3] the spined

[1] On Long Island it has been found by the Bureau of Entomology that the combined length of the larva and pupa stages varies from 17 days in August to 46 days in October and November.

[2] *Megilla maculata* DeG.;

[3] *Hippodamia convergens* Guér.

soldier-bug,[1] and the bordered soldier-bug [2] (fig. 6) are also active destroyers of asparagus-beetle larvæ, which they attack by impaling them upon their long beaks and sucking out their juices. Certain species of wasps [3] and small dragonflies [4] also prey upon the asparagus-beetle grubs. These insects hover about the infested plants until a larva is seen, when they pounce upon it and carry it away. The eggs of this asparagus beetle are attacked by a minute wasplike four-winged fly[5] (fig. 7) which lays its eggs in those of the beetle. Strangely enough, the parasitized eggs hatch and the larvæ emerging from them become full grown, but are destroyed by the parasite larvæ after the beetle larvæ have entered the soil and formed their pupal cells, but before they have changed to pupæ.

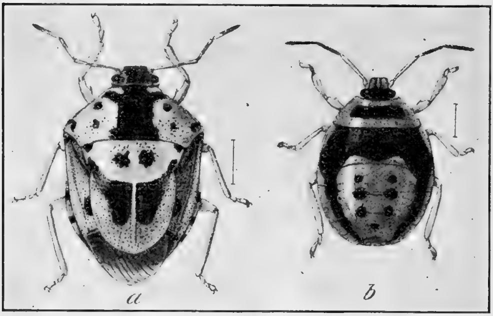

FIG. 6.—The bordered soldier-bug an enemy of the common asparagus beetle: *a*, Adult bug; *b*, young bug, or nymph. Much enlarged.

Asparagus beetles are very susceptible to sudden changes of temperature, and it has been noticed frequently at Concord, Mass., that immense numbers of the hibernating beetles are killed in winter during severely cold spells following "open" weather, millions of their dead bodies sometimes being found under bark and in other hiding places.

The intense heat that prevailed at times during the summer of 1896, especially during the first two weeks of August, though conducive to the undue propagation of some forms of insects, had the opposite effect upon certain species that feed in the larva condition freely exposed upon

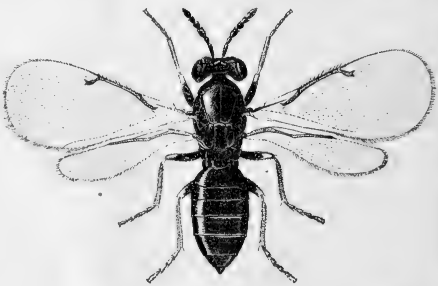

FIG. 7.—*Tetrastichus asparagi*, a parasite of the common asparagus beetle: Adult. Greatly enlarged. (F. A. Johnston.)

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[1] *Podisus maculiventris* Say.
[2] *Stiretrus anchorago* Fab.
[3] *Polistes pallipes* Lep.
[4] *Ischnura posita* (Hagen).
[5] *Tetrastichus asparagi* Cwfd.

the plants. In the vicinity of the District of Columbia this was particularly noticeable in the case of the larvæ of this asparagus beetle. Its eggs, also, seemed to be dried up by the heat. What with the decimation caused by their natural enemies and that caused by the heat, scarcely a beetle or larva was to be found that year after the last of August.

METHODS OF CONTROL.

Fortunately the common asparagus beetle is not difficult of control and ordinarily may be held in repression by the simplest means.

GARDEN REMEDIES.

Hand-picking is of some value in small beds but must of necessity give way to more approved methods for the vast numbers of the beetles that concentrate their forces upon the large areas devoted to this crop in the suburbs of our large cities.

Chickens and ducks are efficient destroyers of asparagus beetles, and as they do no injury to the plant their services are still in requisition for this purpose at the present day.

One of the best remedies against the larvæ is fresh, air-slaked lime, dusted on the plants in the early morning while the dew is on. It quickly destroys all the grubs with which it comes in contact.

Pyrethrum is credited with being useful, and a mixture of soft soap, quassia decoction, and water (about equal parts of the first two to five of the last) is effective against the larvæ.

These remedies, with the exception of air-slaked lime to destroy the larvæ, hardly commend themselves for use on a large scale.

CULTURAL PRACTICES.

A practice in high favor among prominent asparagus growers is to cut down all plants, including seedlings and volunteer growth, in early spring, so as to force the parent beetles to deposit their eggs upon new shoots, which are then cut every few days before the eggs have time to hatch for the first new brood.

Other measures that have been employed with advantage consist in cutting down the seed stems after the crop has been harvested, and again once or twice during the cutting season, or in permitting a portion of the shoots to grow and serve as lures for the beetles. Here these may be killed with insecticides, or the plants, after they become covered with eggs, may be cut down and burned, and other shoots allowed to grow up as decoys. The trap plants should be destroyed as often as once a week. Naturally when the insects have congregated on the tips early in the cutting season, arsenicals and other substances can not be applied and it is necessary, therefore, to cut as deeply and as often as possible without injuring the product for the market.

With concerted action on the part of growers in following out these methods the insects may be held in check in regions where asparagus does not grow wild in too great profusion; elsewhere insecticides must be used. It is well in any case to employ insecticides after the cutting season, since if the insects are destroyed at this time their numbers the next year will be lessened.

THE BRUSHING METHOD.

A simple and inexpensive method of killing the larvæ in hot weather is to beat or brush them from the plants with a stick so that they will drop to the bare ground. The larvæ are delicate creatures, and, as they crawl very slowly, few are able to regain shelter of the plants, but die when exposed to the heated earth.

DUSTING WITH ARSENICALS.

An arsenical, applied dry mixed with flour, as for potato beetles, answers well as an insecticide, destroying beetles as well as grubs, and is of value on plants that are not being cut for food. A mixture of arsenate of lead and air-slaked lime, or plaster, 4 pounds of the former to a barrel of the latter, is recommended. For satisfactory results the lime and arsenical must be applied at frequent intervals, or as often as the larvæ reappear on the beds.

SPRAYING WITH ARSENICALS.

Arsenate of lead has given better results in spraying than any other arsenical. This insecticide has come into very general use in recent years and has superseded Paris green and other arsenicals for the control of leaf-feeding beetles, such as the potato beetles and asparagus beetles. It is less harmful to growing plants and less likely to burn the leaves, adheres better to the foliage, is less troublesome to prepare, and is more effective.[1] In addition the spray, on drying, leaves a white coating on the plants, so that it can be readily determined which plants have been treated and which have not.

Two pounds of dry lead arsenate, or 4 pounds of lead-arsenate paste, to 50 gallons of water or Bordeaux mixture will make a solution of sufficient strength to destroy asparagus beetles and their larvæ. The number of sprayings to be applied depends on local and seasonal conditions. Sometimes a single spraying at the proper time will suffice, but occasionally two or three applications are necessary, especially if rainfall intervenes. 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.

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[1] In Pennsylvania a comparative test was made of the value of Paris green and arsenate of lead, showing that not more than 50 per cent of the insects were killed when Paris green and lime were used, while 90 per cent were killed with arsenate of lead; and when resin soap was added to the arsenate of lead to make the latter adhere more closely to the plants, *all* of the insects were killed on 50 plants treated. In the last experiment the arsenate of lead was used at the rate of 2 pounds to 50 gallons of water, with 5 pounds of resin soap.

SPRAYING APPARATUS.

Extensive experiments have proved that for economy and efficiency the best spraying machinery should be used, even though its initial cost is greater. The "vermorel," "cyclone," and "giant-disk" types of nozzles are the most effective as well as the most economical. When the arsenical is forced through a nozzle of any of these types the spray is mistlike in appearance and adheres to the foliage instead of forming small drops which may roll off. A sprayer of the compressed-air type is the best, the smaller ones being operated by hand and the larger ones by machinery driven by horsepower.

THE TWELVE-SPOTTED ASPARAGUS BEETLE.

A somewhat less injurious species than the preceding is the twelve-spotted asparagus beetle [1] known to many growers as the red species. It is generally distributed in Europe, where it is apparently native, and, although common, not especially destructive. Like the preceding, it lives exclusively on asparagus, and its chief damage is due to the depredations of the hibernated beetles in early spring upon the young and edible asparagus shoots. Later generations attack the foliage, living, for at least a considerable portion of the larva stage, within the ripening berries.

INTRODUCTION AND SPREAD IN THE UNITED STATES.

The presence of this insect in America, as has been stated, was first discovered in 1881 in the vicinity of Baltimore, Md. This beetle was noticed in considerable numbers from the first, showing that it had probably been introduced several years earlier. It was then seen only on volunteer asparagus growing on the salty margin of a river, although beds of cultivated asparagus were plentiful in the immediate vicinity. Two years later it had proved even more troublesome than the common asparagus beetle.

It has been said of this species that it is one of the most interesting insect pests of which we have knowledge. Its mysterious introduction into the United States, the discovery of its presence in Baltimore, the rapid spread from that center, the keen race northward with the common species, their simultaneous arrival in Canada and progress westward, are only a few of the interesting phases of the history of the twelve-spotted asparagus beetle. Nearly every year since then it has been reported in new localities in the United States and Canada, until now it is well distributed westward and northward. In the Niagara peninsula the two species arrived almost simultaneously, the twelve-spotted form being the dominant one.

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[1] *Crioceris duodecimpunctata* L.

DESCRIPTION, SEASONAL HISTORY, AND HABITS.

The mature beetle (fig. 8, *a*) rivals the common species in beauty, but may be distinguished by its much broader back and orange-red color. Each wing-cover is marked with 6 black dots, and the knees and a portion of the under surface of the thorax are marked with black. The beetle, as it occurs on the plant when in fruit, very closely resembles at a little distance a ripening asparagus berry.

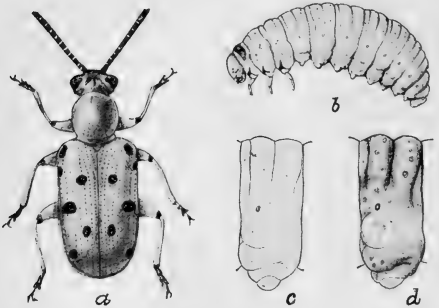

FIG. 8.—The twelve-spotted asparagus beetle: *a*, Beetle; *b*, larva; *c*, second segment of larva; *d*, second segment of larva of the common asparagus beetle. *a*, *b*, Enlarged; *c*, *d*, more enlarged.

The common asparagus beetle dodges around a stem like a squirrel when disturbed, but the twelve-spotted form appears to trust to flight, taking wing more readily. Both species make a loud creaking sound, when handled produced, in the present species, by rubbing the tip of the abdomen against the wing-covers.

The full-grown larva (fig. 8, *b*) measures, when extended, three-tenths of an inch (8 mm.), being of about the same proportions as the larva of the common species, but is readily separable by its orange color. The ground color is light yellowish cream with an overlay of yellowish orange which is most pronounced on the outer portions of the abdominal segments. The head, with the exception of the mouthparts, is also yellowish. The thoracic plate is prominent, divided into two parts, and of a dark-brown color. The second abdominal segments of both species, much enlarged, are shown for comparison at *c* and *d*, figure 8.


FIG. 9.—Eggs of the twelve-spotted asparagus beetle: At left, much enlarged; at right, nearly natural size.

The chief damage inflicted by this species results from the work of the hibernated beetles in early spring upon the young and edible asparagus shoots. Later beetles as well as larvæ appear to feed exclusively on the berries. In Europe this species, although common, is not especially destructive.

The eggs are deposited singly, and apparently by preference upon old plants, toward the ends of shoots which, lower down, bear ripening berries, and they are attached along their sides (see fig. 9) instead of at one end, as with the common species. Soon after the larva hatches it finds its way to an asparagus berry, enters it, and feeds upon the pulp. In due time it leaves this berry for another one, and when full grown it deserts its last larval habitation and enters the earth, where it transforms to the pupa and afterwards to the beetle. The life cycle does not differ materially from that of the common species, and probably the same number of generations are developed, or nearly as many.

REMEDIES.

The remedies for the twelve-spotted asparagus beetle are those indicated for the common asparagus beetle, with the possible exception of the caustic lime and some other measures that are directed solely against the larvæ of that species, but the habit of the larva of living within the berry places it for that period beyond the reach of insecticides. The collection and destruction of the asparagus berries before ripening might be a solution of the problem, but it is questionable if recourse to this measure would be necessary, save in case of an exceptional abundance of the insect. A thorough spraying with arsenate of lead as advised for the common species should be sufficient for its control.

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IMPORTANT PECAN INSECTS AND THEIR CONTROL

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FARMERS' BULLETIN 843

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

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THE PECAN has a number of important insect enemies of more or less extended distribution. Some of these injure the nuts, others the foliage and shoots, and still others the trunk and branches. Owing to the wide diversity in their methods of attack, no general directions for the control of these pests can be given, and in the adoption of remedial measures the peculiar habits of each species must be considered. This bulletin describes the more important insects that injure pecan and suggests the methods that should be followed to avert damage.

IMPORTANT PECAN INSECTS AND THEIR CONTROL.

CONTENTS.

THE pecan industry in the South has developed rapidly. This development, however, has been accompanied by an important increase in the number and destructiveness of the insects attacking the crop. The loss to pecan growers from insect attacks has amounted to hundreds of thousands of dollars annually, and in the absence of preventive measures it is certain to increase. The present bulletin gives results of studies of the more important pecan insects by the Bureau of Entomology.

INSECTS INJURING THE NUTS.

THE PECAN NUT CASE-BEARER.[1]

The pecan nut case-bearer, in its larval or "worm" stage, attacks for the most part the immature nuts and is capable of reducing the crop greatly. During May, shortly after the nuts have set and when they are not much larger than garden peas, the larvæ will be found boring into them, and at the point of attack casting out pellets of frass, or borings, which are held together by means of fine silken threads that form a short silk-lined tube. Nuts injured by this insect always show the characteristic mass of frass protruding from the place where the larvæ gained entrance, which is invariably near the junction of the base of the nut with the stem. During the early part of the season, when the nuts are small, one larva will often destroy several nuts before attaining its full growth.

This nut case-bearer, as well as another species[2] that attacks the pecan in a somewhat similar way, has often been reported as destroying from one-third to three-fourths of the total crop of wild pecans

[1] *Acrobasis hebescella* Hulst.

[2] *Acrobasis caryivorella* Rag.

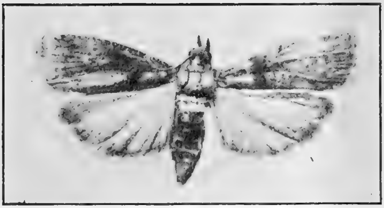

Fig. 1.—The pecan nut case-bearer (*Acrobasis hebescella*): Moth. Much enlarged.

in various localities in Texas. Until very recently this insect has not been reported in the cultivated orchards east of Texas, but within the last few years it has become a serious pest in some localities in Florida, Georgia, Alabama, Mississippi, and Louisiana. It would seem that this species is extending its range of destructiveness, and in view of the large acreage of pecan orchards now bearing or coming into bearing, sooner or later it probably will prove a most formidable pest throughout the greater part of the pecan belt.

DESCRIPTION.

In the course of development the pecan nut case-bearer passes through four distinct stages, namely, the egg, the larva or "worm," the pupa or resting stage, and the adult or moth. The grayish-black moth (fig. 1) has a wing spread of about three-fourths of an inch. The head and thorax are brownish and the abdomen is yellowish gray. The forewings are grayish black and each has a ridge or tuft of long black scales extending across it near the basal end. The hindwings are much brighter than the forewings and without any conspicuous markings.

The egg is irregularly oval in outline. When first laid it is white, with a greenish tinge, but as incubation proceeds it becomes pinkish or reddish. It is iridescent in some lights.

The full-grown larva, or caterpillar (fig. 2, at right), is about one-half inch in length, and the general color of the body is dirty olive green. The skin of the body is wrinkled into folds and is sparsely covered with inconspicuous hairs. The head and mouth parts are dark brown, and the cervical shield, or neck, is pale brown, bisected by an inconspicuous whitish-yellow area.

Fig. 2.—The pecan nut case-bearer: Pupa at left, larva at right. Much enlarged.

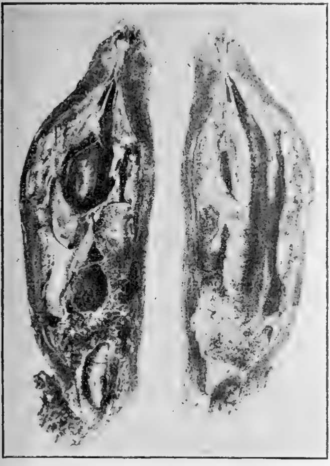

FIG. 3.—The pecan nut case-bearer: Place of pupation in pecan nut.

The pupa (fig. 2, at left) is brown and of the usual form. It is rounded at the posterior end, and here it bears a cluster of small hooked spines. Pupation always takes place in the infested nut or shoot (fig. 3), and upon emergence of the moth the pupal skin is not left protruding as it is in the case of certain other insects.

SEASONAL HISTORY AND HABITS.

This insect has three distinct generations during the year. The larvæ which have lived through the winter become active at the time when the foliage appears in the spring and they attack the young and tender shoots, in which they tunnel by eating out the interior, leaving the outside intact (fig. 4). The moths of the first generation, which are the progeny of the moths developing from the hibernating larvæ, make their appearance from May 7 to 24 and soon after emergence lay their eggs. The eggs are invariably deposited on the calyx end of the nut, and usually at or near the base of the calyx lobes. From 5 to 7 days are required for the eggs to hatch. The larva, as soon as it gnaws its way out of the eggshell, crawls to the base of the young nuts, where it commences feeding. It bores its way into the nuts (fig. 5) and as it feeds it webs together, by means of silken threads, particles of frass and excrement which assume somewhat the shape of a tube smoothly lined with grayish white silk. These tubelike masses of frass are readily seen extruding from the base of infested nuts (figs 5 and 6). The larva period lasts from 22 to 29 days and the pupa period from 9 to 13 days.

FIG. 4.—The pecan nut case-bearer: Young pecan nut infested by larva.

Most moths of the second generation emerge from the middle of June up to the first week of July. It was determined that all moths in a large series under observation actually emerged during the period from June 11 to July 15, but the maximum emergence occurred during the last week in June. Second-brood larvæ attack the nuts in the same manner as those of the first generation, but usually the injury to the nut crop by these larvæ is not so great.

Most of the moths of the third generation appear during the first three weeks in August. The larvæ from this generation do little or no damage to the nuts, which usually are beginning to harden at this time, and they seem to prefer to feed in the petioles or tender shoots. The winter is passed as immature larvæ in cocoons or hibernacula, which are formed around the buds. In rearing cages it was observed that larvæ which hatched from eggs laid by third-brood moths usually fed very little before constructing winter cases around the buds. It was noticed, however, that a very few larvæ fed extensively and transformed to pupæ, from which moths emerged during the last part of September, thus indicating a fourth generation. But observations in pecan orchards failed to show any indications of a fourth generation.

CONTROL MEASURES.

The pecan nut case-bearer is already an established pest in certain important pecan-growing sections, and because of its increasing destructiveness certain experiments have been conducted for the determination of positive means of control. During the seasons of 1915 and 1916 series of spraying experiments were conducted in a pecan orchard at Monticello, Fla. All sprayed plats were treated with 1 pound of powdered arsenate of lead plus 3 pounds of slaked stone lime to each 50 gallons of water. In all cases the material was applied with a well-equipped gasoline-power outfit, and a pressure varying from 150 to 200 pounds was maintained.

The results of spraying experiments for 1915 are shown in Table 1.

TABLE 1.—*Spraying experiments against the pecan nut case-bearer, Monticello, Fla., 1915.*

Plat No.	Number of count trees.	Date of spraying.	Total nuts for season.	Number of nuts infested.	Number of sound nuts.	Per cent of sound nuts.
I	5	May 15 and 27 and June 24	3,559	748	2,811	78.98
II	5	May 15 and June 24	3,915	756	3,159	80.68
III	5	May 27 and June 25	4,366	1,125	3,241	74.23
IV	5	Check, unsprayed	1,923	779	1,144	59.49

It will be seen that Plat I, which received three applications, gave 78.98 per cent of sound nuts, and showed a benefit of 19.49 per cent over the check or unsprayed plat, which had only 59.49 per cent of sound nuts. Plat II, which received only two applications, yielded a somewhat greater percentage of sound nuts, while Plat III, which had only one application, yielded 74.23 per cent of sound nuts. The benefit for each plat over the check plat is shown in percentages as follows: Plat I, 19.49; Plat II, 21.19; and Plat III, 14.74. It is worthy of mention that out of the 40.51 per cent of infested nuts on

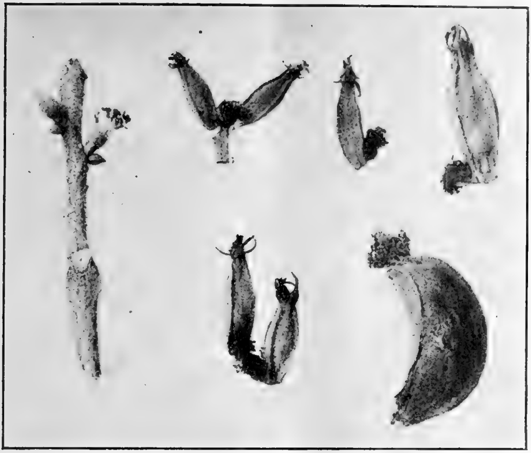

FIG. 5.—The pecan nut case-bearer: Young pecans showing injury by larva.

FIG. 6.—The pecan nut case-bearer: Cluster of infested young pecan nuts.

the unsprayed plat (Plat IV) the injury by the first brood of larvæ amounted to 29.90 per cent, while the second-brood infestation was only 10.61 per cent, thus showing the proportional attacks on the nut crop by the first and second broods of larvæ.

The results of the spraying experiments for the season of 1916 are shown in Tables 2 and 3. The two series of experiments, as outlined in these tables, were conducted in the same orchard, but a distance of fully one-fourth of a mile separated them.

TABLE 2.—*Spraying experiments against the pecan nut case-bearer, Monticello, Fla., 1916.*

Plat No.	Number of count trees.	Date of spraying.	Total nuts for season.	Number of nuts infested.	Number of sound nuts.	Per cent of sound nuts.
I	5	May 12 and 24 and June 24	3,929	190	3,739	95.16
II	5	May 12 and 24	4,608	302	4,306	93.44
III	5	May 12 and June 20	5,522	407	5,115	92.62
IV	5	Check, unsprayed	3,352	581	2,771	82.67

As will be noted in Table 2, the best results were obtained on Plat I, which received three applications, there being 95.16 per cent of sound nuts. The infestation in the unsprayed plat (IV), however, was not severe, since 82.66 per cent of the nut crop came through in sound condition. The actual percentage of infestation in this plat was 17.33 of the total crop, 12.14 being due to the first-brood larvæ. Plats II and III showed 93.44 and 92.62 per cent of sound nuts, respectively. The benefit to each sprayed plat over the check (Plat IV) is given in percentages as follows: Plat I, 12.49; Plat II, 10.77; and Plat III, 9.95.

TABLE 3.—*Spraying experiments against the pecan nut case-bearer, Monticello, Fla., 1916.*

Plat No.	Number of count trees.	Date of spraying.	Total nuts for season.	Number of nuts infested.	Number of sound nuts.	Per cent of sound nuts.
V	5	May 12	2,461	546	1,915	77.81
VI	5	Check, unsprayed	1,569	380	1,189	75.78
VII	2	May 24	474	77	397	83.75
VIII	2	May 12 and 24	690	70	620	89.85

As will be noted in Table 3, Plat V, which received one application on May 12, gave only 77.81 per cent of sound nuts, as compared with 75.78 per cent of sound nuts on the unsprayed plat (VI), showing a benefit of only 2.03 per cent from the treatment. Plat VII, which received one application on May 24, showed 83.75 per cent of sound nuts, while Plat VIII showed a percentage of 89.85 of sound nuts. The benefit to each sprayed plat over the check (Plat VI) is shown in the following percentages: Plat V, 2.03; Plat VII, 7.97; and Plat VIII, 14.07.

In working out control measures for this pest, it has been determined that the spray applications must be made during very limited periods in order that satisfactory results may be obtained. In spraying for this species timeliness and thoroughness of application are two essentials that must be observed most faithfully, for even the slightest delay or carelessness in applying the spray is likely to result in very disappointing returns from the treatment. Since the eggs of the first brood of moths are hatching for a period of fully two weeks, and as the nuts are growing very rapidly at this time, it is necessary to make two applications for the protection of nuts against infestation by the first-brood larvæ, which, as has been stated before, invariably cause the most damage to the crop. It has been found necessary to spray once for the second-brood larvæ, which usually begin to bore into the nuts shortly after the middle of June.

RECOMMENDATIONS.

Investigations conducted so far show that the best method of control against the pecan nut case-bearer is spraying with arsenate of lead. The arsenate of lead should be used at the rate of 1 pound of the powdered form or 2 pounds of the paste form to each 50 gallons of water, to which should be added the milk of lime from 3 pounds of slaked lime. Three applications will be required and should be made at the following periods:

First.—Shortly after the nuts have set, at which time they are about the size of garden peas.

Second.—One week or ten days after the first application.

Third.—Four or five weeks after the second application.

The date for the first application at Monticello, Fla., during the season of 1916, was found to be May 12. It should be borne in mind, however, that the time of spraying probably will vary somewhat according to latitude and for different seasons.

THE PECAN SHUCKWORM.[1]

A rather slender, white larva or caterpillar (fig. 7, at right), about three-eighths of an inch in length, is found mining the shucks of pecan and hickory during the autumn months. This caterpillar is referred to commonly as the pecan or hickory shuckworm, or huskworm, and for the discussion of the insect in this bulletin the name pecan shuckworm is employed. The mining or tunneling of the shucks often results in the improper development of the nut kernels and

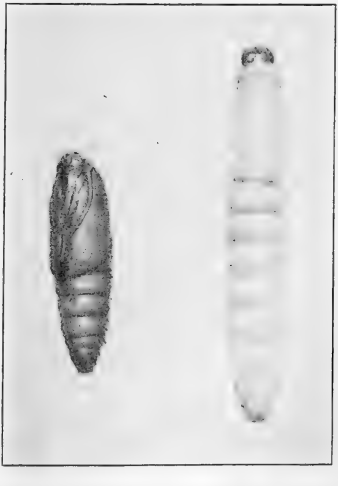

FIG. 7.—The pecan shuckworm (*Laspeyresia caryana*): Pupa at left, larva at right. Enlarged.

[1] *Laspeyresia caryana* Fitch.

prevents the natural separation of the shucks from the nutshells. Nuts attacked by the shuckworm during the late fall usually will mature in fairly good condition for the market, but if the injury takes place early it will result in inferior or unmarketable fruit. Sooty trails on the shell of the nuts often result from the attack of the larvæ, the nuts sometimes being so discolored as to lessen their market value. The damage is not restricted entirely to the matured nuts, for during the summer the early generations of larvæ attack the small, green nuts by eating out the interior, causing them to fall to the ground. (Fig. 8.) Injury of this type is not so noticeable or so widespread as that which takes place in the fall, but it plays no small part in the reduction of the nut crop.

FIG. 8.—The pecan shuckworm: Larva in shuck of nearly matured pecan nut. Enlarged.

Besides attacking the pecan, this insect feeds upon the nuts of the various species of hickory, where the injury it does is precisely like that done to the pecan, except that the destruction of the small, green nuts seems to be greater. Occasionally the larvæ will be found subsisting on the galls formed by a certain species of aphid.[1]

Before nuts have set on pecan trees larvæ sometimes will be found boring into and tunneling the succulent shoots, but this form of injury is very uncommon, as this species is primarily a nut-infesting insect.

DESCRIPTION.

This insect passes through four stages: The egg, the larva, the pupa, and the adult or moth. The moth of the shuckworm (fig. 9) is smoky black, mixed with iridescent bluish and purplish tinges, and the forewings have a series of short, yellowish streaks across their front margins. The moths are rather variable in size, but the maximum expanse of wings is rarely more than three-fifths of an inch. Because of their protective coloration the moths are seldom observed in pecan orchards, even by keen observers.

The egg is small, whitish, and more or less oval, and under high magnification its surface is seen to be wrinkled. The eggs are de-

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[1] *Phylloxera caryaecaulis* Fitch.

posited singly on either the nuts or the foliage. During the summer months the average time of hatching is about 5 days, but the time may vary considerably, depending upon the weather conditions.

FIG. 9.—The pecan shuckworm: Moth. Enlarged.

The larva upon hatching is a very small, whitish, 16-footed caterpillar, but when full grown it is about three-eighths of an inch in length and has a creamy white body and light brown head (fig. 7, at right). It is in the larval stage that injury is done to the nuts.

The pupa (fig. 7, at left), which is brownish, is always found within the infested nut. Before transformation to the pupa stage the larva prepares a small silk-lined cocoon, and cuts a small circular hole on the outside of the shuck, which facilitates the issuing of the moth. Upon the emergence of the moth the pupal skin is extended a short distance through the circular cut (see fig. 10), the lid of which remains attached to the nut in a sort of trap-door arrangement.

SEASONAL HISTORY AND HABITS.

The number of broods of the pecan shuckworm probably will be found to vary from one to three for the country as a whole. In the extreme southern portion of its destructive range apparently

FIG. 10.—The pecan shuckworm: Pupal skins protruding from shucks of pecan nuts.

three generations occur each year, but in the Northern States, where the insect subsists on the various species of hickory, there is perhaps only one generation. The moths, which develop from larvæ that spend the winter in the fallen pecan or hickory shucks, begin to appear in northern Florida as early as the middle of February and continue to emerge until the latter part of April, the spring emergence thus covering a period of more than two months. It has been determined, however, that the maximum emergence of moths occurs during the last two weeks of March. Extensive observations have shown that the vast majority of moths come forth before the appearance of the pecan foliage and nuts, and this apparently accounts for the extremely small numbers of first-brood larvæ that attack the pecan trees. The development of the foliage and nuts of the pignut [1] and white hickory [2] is much earlier in the spring than that of the pecan, and it seems that the emergence of moths is timed for these host plants. In this connection it is interesting to note that considerable damage always is done to the very small hickory nuts by the first brood of larvæ, while the very small pecan nuts seem to escape such injury. Some first-brood larvæ will be found attacking the tender shoots of pecan, but the apparent reason for the immunity from attack of the recently set pecan nuts is the fact that the emergence of moths does not coincide very well with the development of the nut. Since the moths are capable of flying some distance, it is likely that for the purpose of egg-laying some of those emerging from pecan shucks during the spring succeed in reaching hickory trees growing adjacent to pecan orchards.

The moths deposit their eggs on the young nuts or foliage, and during the summer months the period of incubation lasts about 5 days. Upon hatching the larvæ gnaw their way into the nuts by making a pinhole entrance, and proceed to mine the shucks in the nearly matured fruit, but some larvæ bore into the interior of the green nuts and cause them to drop to the ground.

During the spring and summer the larvæ usually feed from 3 to 4 weeks, and transform to pupæ within the green nuts or the shucks of the matured fruits. The length of the pupa stage is found to range from 9 to 45 days. During the summer months it lasts about 11 days, while most of the pupæ from overwintering larvæ transform to moths in 18 days, although some few moths do not issue for a considerably longer period. The pupation of the overwintering larvæ occurs from about the first of February until the middle of April.

As stated before, the larvæ of the first brood feed for the most part on the small hickory nuts, but during the last days of June and through July and August, although continuing their depredations on the hickories, the larvæ will be found attacking the green pecan nuts. The first and second broods of larvæ destroy the interior of the nuts and invariably cause them to drop. The last brood of larvæ, which attacks the nearly matured nuts with hard shells (fig. 11), feeds only on the shucks, in which they mine and attain full growth before the advent of cold weather. They pass the winter as larvæ in the shucks on the ground or in shucks that remain on the trees.

[1] *Hicoria glabra* Britt. [2] *Hicoria alba* Britt.

CONTROL MEASURES.

It is impracticable to spray for the control of this pest, because of the great difficulty encountered in destroying the larvæ before they enter the nuts or shucks. It will be found impossible also to destroy the larvæ and pupæ, or prevent the emergence of moths, by plowing under the shucks during the fall or winter months, as experiments have shown that the burial of infested shucks as deep as 6 inches during the late fall did not prevent many moths from emerging the following spring.

Since the insect passes the winter as larvæ in the shucks on the ground, it seems that the best method of control is to gather and destroy all shucks, and this should be done immediately after the harvesting of the nut crop, or not later than the middle of February. By the adoption of this method the majority of the larvæ will be killed and thus the infestation of the pecan orchard during the ensuing season will be prevented.

FIG. 11.—The pecan shuckworm: Larval injury to matured pecan nuts.

Hickory trees growing adjacent to pecan orchards will prove always a source of infestation by this pest as well as other injurious insects. It would seem, therefore, that the cutting down of hickory trees in the immediate vicinity of the orchards would be a very good procedure for pecan growers.

THE PECAN WEEVIL.[1]

The pecan weevil, often termed the hickory-nut weevil, has long been known in some sections as a serious drawback to the successful culture of pecan nuts as well as hickory nuts. The greatest damage reported has been on the wild pecans in Texas, but this insect is also a formidable pest in certain restricted localities in Georgia, Mississippi, and Louisiana, where the so-called paper-shell pecans are grown on a large scale. The injury by this weevil is recognized readily by the circular holes in the nutshells (fig. 12), which are made by the grubs in leaving the nuts to enter the ground for hibernation and subsequent pupation. One grower in middle Georgia reported that 90 per cent of his Stuart pecans and 15 per

[1] *Balaninus caryae* Horn.

cent of the Schley variety were injured by this insect, but the orchard in question was adjacent to a 250-acre woodland containing many native hickory trees the nuts of which were infested severely. No

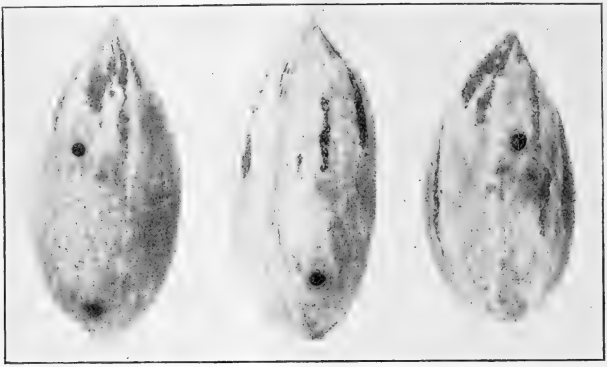

FIG. 12.—The pecan weevil (*Balaninus caryae*): Exit holes of larvæ in pecan nuts.

doubt the serious infestation of the nut crop in this orchard was in a large measure attributable to the close proximity of hickory trees. Another grower in Georgia reported extensive damage to Rome and Stuart varieties of pecan, and in one locality in Louisiana this weevil is reported to have caused a loss of 65 per cent of the pecan yield.

Although this insect is distributed very widely throughout the country, occurring on both the wild and cultivated pecans as well as native hickory nuts, thousands of acres of pecan orchards have not yet suffered any loss from attack, so far as is known. One grower in Georgia found that out of a crop of 48,000 pounds, so far as he observed, not a single nut was affected by the weevil. Similar reports have been received from large pecan growers in

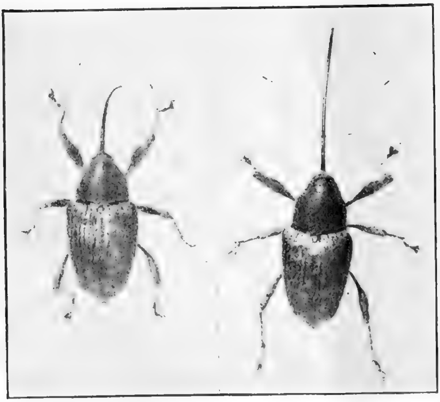

FIG. 13.—The pecan weevil: Adult male at left, adult female at right. Enlarged.

Florida, Mississippi, Louisiana, and Texas. The development of this insect shows four stages: (1) The egg, (2) the larva or grub, (3) the pupa, and (4) the adult or weevil. The parent of the grubs which destroy the interior of the nuts is a small, long-snouted beetle (fig. 13) closely related to the chestnut weevil. The beak, or snout, of the female is much longer than that of the male. The general color of the beetles is dull, dark brown, with a slight tinge of gray.

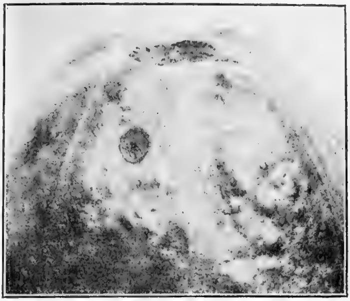

FIG. 14.—The pecan weevil: Egg puncture in the pecan shuck. Enlarged.

The eggs are small, somewhat elongated, irregularly shaped, and translucent white. With her long, slender, but strong beak the female beetle makes a small hole or gallery through the shuck and shell (fig. 14) and with her ovipositor inserts the eggs into the kernel of the nut.

The larva is a robust, yellowish white grub, with a red or light reddish brown head. It is by this stage of the insect that the kernels of the nuts are destroyed (fig. 15). When the larvæ reach maturity they leave the nuts by gnawing circular holes in the shells, and immediately enter the soil to a depth of about 6 to 8 inches and there pass the winter.

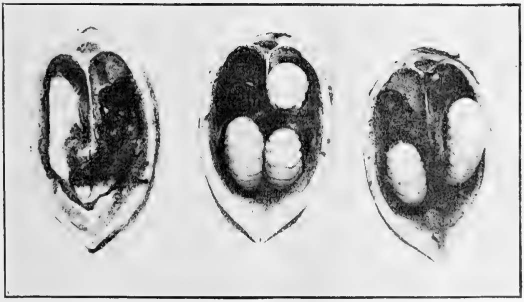

FIG. 15.—The pecan weevil: Grubs, or larvæ, within pecan nuts.

The pupa is of the usual form and is somewhat lighter in color than the larva. It is formed within the soil, in a small earthen cell made by the larva at the time of entering the ground.

SEASONAL HISTORY.

In the South the beetles emerge from the ground and appear on the pecan trees during August and September. Shortly after emergence they are to be found laying eggs in nuts that are approaching maturity. Adults may be found in the ground as late as November, as one specimen, apparently fully developed, was taken on November 23, 1915, about 8 inches below the surface of the soil. The main egg deposition takes place during the first half of September, but apparently eggs are laid over a much longer period, as is evidenced by the time during which larvæ leave the nuts. It has been found that the egg stage lasts about 9 days, and as many as 7 eggs may be deposited in a single nut, although the usual number, perhaps, is 3. According to the writer's records, the larvæ are gnawing their way out of the nuts from September 28 to November 25, although certain observers have reported that the larvæ may leave the nuts as late as January. Immediately upon leaving the nuts they enter the soil to a depth of 6 inches or more for the purpose of hibernation.

CONTROL MEASURES.

The fumigation of chestnuts with disulphid of carbon has been used for a long time as a remedy against the chestnut weevil, and no doubt this treatment will prove effective against the pecan weevil. The nuts to be fumigated should be placed in a tight box or barrel or other receptacle provided with a tight-fitting lid. The disulphid of carbon should be used at the rate of 1 ounce to each bushel of nuts, and fumigation should last for from 24 to 48 hours. The chemical should be placed in a shallow dish or pan on the top of nuts, and immediately after the liquid is poured into the dish the lid should be put in place, care being taken to have it fit tightly. After the nuts have been exposed to the fumes of this gas for from 1 to 2 days, all larvæ will have been killed and the lid should be removed to expose the nuts to the air. Since the vapor of disulphid of carbon is very inflammable when mixed with air, fire should be kept away from it.

The extensive cultivation of the soil in pecan orchards should result in the destructuon of many of the larvæ and pupæ by their exposure to the air and to natural enemies, and where the weevil is prevalent this practice is recommended. After the harvesting of the crop in the fall, hogs should be pastured in the orchard, as they will find the nuts that have been overlooked, and by their rooting into the soil should destroy many of the hibernating larvæ.

INSECTS INJURING THE FOLIAGE AND SHOOTS.

THE PECAN LEAF CASE-BEARER.[1]

The pecan leaf case-bearer is one of the worst pests affecting the culture of pecans, and it occurs in very injurious numbers in orchards in the southern portion of the pecan-growing area, extending from Florida to Texas. Although this insect has been reported definitely

[1] *Acrobasis nebulella* Riley.

from practically all the Southern States in which pecans are grown, it probably ranks as a serious pest only in Florida and the southern parts of Georgia, Alabama, Mississippi, Louisiana, and Texas. The insect occurs also in some of the Northern and Middle Western States where the pecan is not grown, and here it subsists on the various hickories. Generally speaking, the pecan leaf case-bearer is distributed over approximately the same territory as are its preferred hosts, namely, the pecan and hickories. Evidently certain climatic fac-

FIG. 16.—The pecan leaf case-bearer (*Acrobasis nebulella*): Injury to young pecan buds in spring by larvæ.

tors limit the destructiveness of this species, and because of these conditions it has not been able, apparently, to become a pest in the northern part of the pecan-growing sections.

The most serious damage by the leaf case-bearer is done during the early spring and is inflicted by the "worms," which emerge from their winter cases and feed voraciously upon the unfolding buds and leaves. (Fig. 16.) These "worms," or larvæ, are small at this time and dark brown, but soon change to dark greenish as they feed upon the foliage. Upon leaving the winter cases the larvæ enter the buds at the tips and partake of their first meal after having spent several months in hibernation. On badly infested trees the buds and tender leaves suffer serious injury (fig. 17), and often the foliage is consumed by the larvæ as fast as it puts forth. It is not unusual to see pecan trees kept in a defoliated condition for weeks during the spring on account of the attacks of this insect. (See fig. 18.) Since the larvæ are not at all discriminating in their feeding habits, devouring the blossom buds as well as the leaf buds, they are capable of reducing greatly the yield of nuts for the current season, besides leaving the trees in a more or less weakened condition.

FIG. 17.—The pecan leaf case-bearer: Injury to pecan foliage and flowers.

DESCRIPTION.

As is the case with all moths, the pecan leaf case-bearer has four distinct stages, namely, the egg, the larva, the pupa, and the adult, or moth. The moth (fig. 19) measures about two-thirds of an inch across the expanded wings and presents a wide variation in color. The head, thorax, and base of forewings and legs are snow-white in the males, but in the females these parts are dusky gray. The abdomen is whitish marked with brown. The outer two-thirds of the forewings is gray, with blackish blotches or spots, which are somewhat variable, and not far from the base of the forewings is a reddish brown stain.

The egg (fig. 22) is oval and white, with a slight greenish tinge.

The larva (fig. 20), which is the form that inflicts the injury to buds and foliage, is a dark green, cylindrical caterpillar, measuring a little over a half-inch in length when fully grown. The head is rounded, shiny dark brown or black. The general color of the body is very dark green, except the prothoracic shield, which is somewhat lighter. The skin of the body is very much wrinkled into folds, and the entire body is sparsely covered with fine long hairs.

The pupa (fig. 21), to which the full-grown larva changes, is of the usual form and without conspicuous markings. When first formed it is fairly dark brown, with a tinge of olive green, but with age it turns to a deep shiny mahogany brown. The pupa is formed within the larval case, and upon the emergence of the moth the pupal skin is not extruded, as is the case with some other moths.

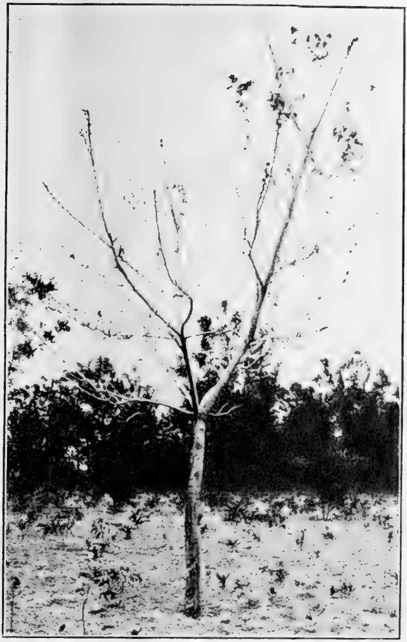

FIG. 18.—The pecan leaf case-bearer: Pecan tree defoliated.

SEASONAL HISTORY AND HABITS.

Only one generation of the pecan leaf case-bearer develops during the course of a year, but more or less variation exists in the development of the different stages, as will be shown presently. For instance, from material under observation during the season 1913 it was determined that the moths, numbering in all 269, emerged between May 9 and July 12, inclusive. During 1914 the dates of issuance for 385 moths varied from May 15 to August 5, and during 1915 the dates at which the 591 moths emerged varied from May 22 to July 23. For the three years the time of greatest, or maximum, emergence was the same, being the latter half of June. Because of the wide variation in moth emergence a corresponding variation occurs also in the time of egg laying. Eggs are deposited always on the underside of the leaves and usually near the junction of the vein with the midrib. (Fig. 22.) The egg stage has been found to last from 6 to 9 days, the average being 7.14 days.

FIG. 19.—The pecan leaf case-bearer: Moth, or parent insect. Enlarged.

The eggs hatch from about the middle of May until the latter part of July or the first few days in August, depending more or less upon the weather conditions. When the young larvæ gnaw their way out of the eggshells they commence feeding upon the portion of the leaflets immediately adjacent to the place where egg laying or oviposition occurred. (Fig. 23.)

FIG. 20.—The pecan leaf case-bearer: Larva and case. Enlarged.

Throughout the summer and during the early fall the larvæ feed very sparingly upon the foliage, and as they extend their feeding quarters they enlarge their little winding cases (fig. 23), which afford very good protection for them. Although they may feed for nearly three months, or even longer in some instances, they rarely attain a length greater than six one-hundredths of an inch in the fall. During the latter part of September they begin to seek winter quarters around the buds, and here they construct small, compactly woven, oval cases known as hibernacula (fig. 24), and by the middle of October practically all larvæ have left the foliage and are to be found snugly protected in these cases. Shortly before the foliage begins to drop in the autumn the little larvæ abandon the leaves upon which they have been feeding and attach their winter cases securely to the buds and twigs. They remain in hibernation until the latter part of March or the first part of April, at which time the buds on pecan trees usually begin to open.

FIG. 21.—The pecan leaf case-bearer: Pupa. Enlarged.

Just as the buds are opening, the larvæ emerge from their winter cases and attack the unfolding leaves. Their pernicious feeding habits at this time result in serious injury to the foliage and in reducing greatly the yield of nuts. The larvæ feed very voraciously during the spring and some of them reach full growth as early as the last days in April, but the majority do not attain full growth until May or early in June. The larvæ always transform to pupæ within their cases (fig. 25), and just before pupation takes place they spin a flimsy layer of silk over the free end of their cases. The pupa period has been found to cover from 16 to 23 days, the average being a trifle over 17 days. The first adults make their appearance about the middle of May and moths continue to come forth until the first week in August. Thus the life cycle of this insect, which it will be seen covers the entire year, is completed.

CONTROL MEASURES.

Although the pecan leaf case-bearer is attacked by a number of parasitic insects, it has been found that the parasites or other natural enemies [1] can not be relied upon to control this pest, but artificial measures of control can be instituted successfully and practically to check its ravages.

FIG. 22.—The pecan leaf case-bearer: Eggs along midrib on lower surface of pecan leaf. Enlarged.

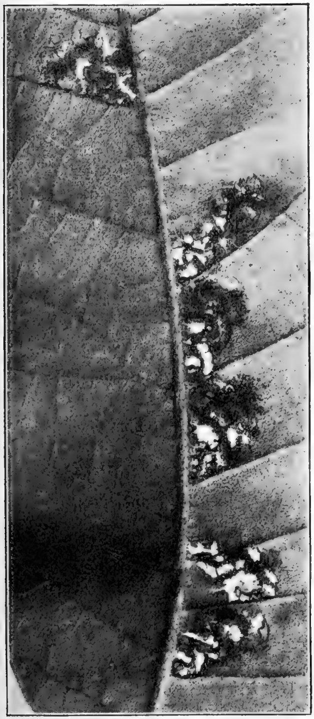

FIG. 23.—The pecan leaf case-bearer: Injury by newly hatched larvæ on lower surface of pecan leaf. Enlarged.

Investigations conducted during the last three years show conclusively that the pecan leaf case-bearer can be controlled by spraying with arsenate of lead during the late summer. The arsenate of lead should be used at the rate of 1 pound of the powdered or 2 pounds of the paste form to each 50 gallons of water, to which should be added 3 pounds of slaked stone lime. Under no circum-

[1]The following parasites have been reared from this species: *Itoplectis conquisitor* Say, *Triclistus apicalis* Cress., *Calliephialtes grapholithae* (Cress.), *Pristomerus* sp., *Macrocentrus* sp., *Meteorus* sp., *Habrobracon variabilis* Cush., *Orgilus* sp., *Secodella acrobasis* Cwfd., *Spilochalcis vittata* (Fab.), *Cerambycobius* sp., *Trichogramma minutum* Riley, *Exorista* sp., and *Leskiomima tenera* Wied. Three species of birds, namely, the blue jay, the mockingbird, and the orchard oriole, have been observed feeding upon the larvæ.

FIG. 24.—The pecan leaf case-bearer: Winter cases, or hibernacula, around pecan bud. Enlarged.

FIG. 25.—The pecan leaf case-bearer: Larvæ in their cases and injury to pecan leaflets.

stances should the arsenate of lead be used without the addition of lime, as more or less serious injury to the foliage or nuts is likely to result. Spraying may be done with the same degree of effectiveness from the first part of August up to the middle of September. Care should be taken not to delay the spraying too long in the fall, as observations have shown that some larvæ seek hibernation quarters toward the latter part of September, although the vast majority of them do not construct winter cases until the first week in October. It should be borne in mind also that only the larvæ that have fed on poisoned foliage will be killed. Remembering these points, growers should realize the importance of spraying at the proper time and apply the poison thoroughly to all parts of the foliage, especially the under side, upon which the larvæ are feeding. Only one thorough application is necessary to control this pest in pecan orchards, even though the infestation is most severe. It is unnecessary to spray more than once for this pest providing the spray is applied thoroughly at the proper time.

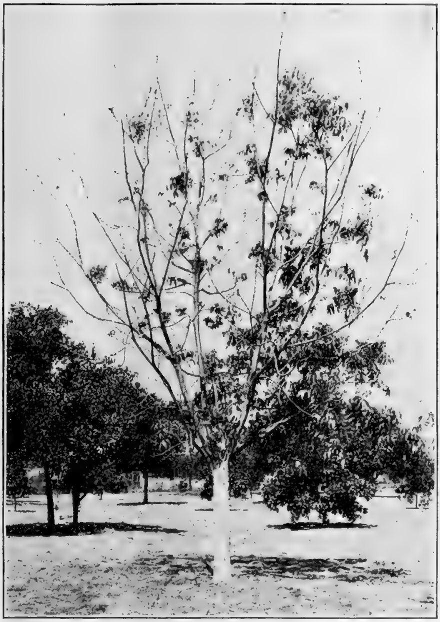

FIG. 26.—The pecan cigar case-bearer (*Coleophora caryaefoliella*): Pecan tree largely defoliated by this insect.

THE PECAN CIGAR CASE-BEARER.[1]

The pecan cigar case-bearer usually is to be considered as a pest of only minor importance, but reports are received of its occurrence in injurious numbers in pecan orchards during the spring months and of the infliction of serious damage to the buds and foliage. (Fig. 26.) This insect does not confine its attacks to the pecan, as it feeds upon the various species of hickory and the black walnut. The pecan cigar case-bearer is distributed over a wide range of the country,

[1] *Coleophora caryaefoliella* Clem.

FIG. 27.—The pecan cigar case-bearer: Type of injury by larva to pecan leaflets.

extending from Florida to the extreme western border of Texas, and as far north as New Hampshire. When the buds of pecan trees are opening, or just after they have begun to unfold, the hibernating larvæ become active and attack them, continuing their feeding operations on the foliage (fig. 27) until about the middle of May (in Florida), when they become full grown and transform to pupæ within the larval cases (fig. 28, *b*, *c*). The pupa period lasts about two weeks, and during June the moths (fig. 28, *a*) appear in numbers on the pecan. The eggs are deposited on the foliage and they hatch within a few days. Upon hatching, the larvæ feed first as leaf-miners, but later in the season they construct the small cases, in which they feed upon the leaves until a short time before the foliage drops in the fall. The larvæ migrate then to the twigs or larger limbs or trunks, where they attach their cases and spend the winter.

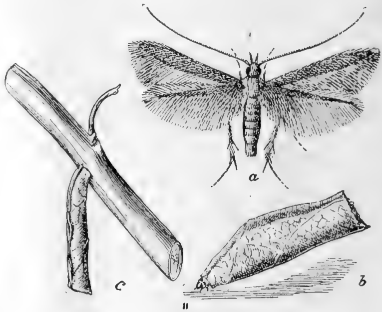

FIG. 28.—The pecan cigar case-bearer: *a*, Moth; *b*, *c*, larvæ in cases. Enlarged. (Russell.)

CONTROL MEASURES.

If this insect occurs in injurious numbers in the spring it can be controlled readily by spraying the trees with arsenate of lead at the rate of 1 pound of the powdered or 2 pounds of the paste form to each 50 gallons of water, to which should be added 3 pounds of slaked stone lime. This species, however, rarely is abundant enough in orchards to call for special treatment. In pecan orchards in which spraying is directed against the more injurious pests the pecan cigar case-bearer rarely will be a source of trouble, as the larvæ of this and the other species are killed by the same treatments.

THE PECAN BUD-MOTH.[1]

The pecan bud-moth is a pest of greater or less importance in the pecan orchard and nursery. At times it becomes so abundant that the damage caused by the larvæ feeding upon the terminal buds of pecan nursery stock entails considerable loss to nurserymen. This insect evidently occurs throughout the pecan-growing region, as reports of damage have been received from most of the Southern States. Besides feeding upon the pecan, it has been recorded doubtfully from various hickories, and doubtful records exist of its occurence on the black walnut.

DESCRIPTION.

The general color of the moths is gray, mottled with blackish-brown patches and streaks, and the expanse of wings is just a little more than half an inch. The blackish-brown patches on the forewings are arranged in a zigzag fashion from the base of each wing across its middle to the tip. The hindwings are without markings and are dusky gray, with the outer margin somewhat darker. The moths are very active and are often found frequenting the tree trunks, on which they rest head downward. When disturbed the moth will fly away in a jerky manner for a short distance and then suddenly wheel about to return to the tree trunk that it just left.

FIG. 29.—The pecan bud-moth (*Proteopteryx bolliana*): Pupa at left, larva at right. Enlarged.

The eggs (fig. 30) are small, oval, whitish, and iridescent in some lights. When the trees are in foliage the eggs are laid upon the upper surface of the leaves, but before the buds push forth in the spring eggs are often found deposited on the twigs.

When full grown the larva (fig. 29, at right) is about five-eighths of an inch in length. The body, which is sparsely covered with fine hairs, is yellowish green, and through

[1] *Proteopteryx bolliana* Sling.

its semitransparent skin can be seen the brownish contents of the alimentary canal. The head and cervical shield, or neck, are shiny dark brown in color in full-grown larvæ, but on very young larvæ they are jet black.

FIG. 30.—The pecan bud-moth: Eggs on pecan leaflet.

The pupa (fig. 29, at left) is of the usual light-brown color. The size varies somewhat, but the length rarely is more than a third of an inch. The pupæ usually are formed in rolled-up leaves or infested buds, but occasionally they can be found under bark scales or at the crown of the tree.

SEASONAL HISTORY.

The number of generations a year varies somewhat in different sections. In the extreme southern portion of its distribution five or six occur during the course of a season. The pecan bud-mouth passes the winter in the adult stage. As soon as the buds on the pecan trees begin to open, the moths commence to lay eggs, which usually are deposited on the branches near the buds, but after the foliage appears the eggs are laid invariably on the upper surface of the leaves. (Fig. 30.) The eggs hatch in from 3 to 6 days, depending upon the temperature. The larvæ feed from 21 to 29 days, the average being about 25 days. The pupa stage lasts from 8 to 13 days, but the average period is about 10 days. The average life-cycle period is 40 days—5 days being spent in the egg stage, 25 days as larva, and 10 days as pupa.

CONTROL MEASURES.

Ordinarily this bud-moth does not occur in sufficient numbers to be ranked as a serious pest of the pecan. In bearing pecan orchards it is rarely troublesome, but during some seasons it is responsible for considerable damage to the pecan nursery trees. This species is primarily a bud feeder, and in attacking the terminal buds on the young trees it causes a stunted growth as well as excessive branching. This feature is especially objectionable from the nurseryman's point of view, since the pecan nursery stock is sold according to its height. It has been observed that nursery trees growing vigorously usually open and unfold their terminal buds so rapidly that the larvæ apparently do not have sufficient time to inflict serious damage. It has been observed, further, that the larvæ feed on the foliage (fig. 31) if compelled to do so by the rapid growth of the tree, and under these conditions they will eat the outer parts of the leaves. During dry seasons, especially in the spring of the year, pecan nursery stock grows very slowly and is seriously injured by larvæ of the bud moth. As a nursery practice it is strongly recommended that the trees be kept in a vigorous growing condition by thorough cultivation and fertilization. Spraying with arsenicals during the spring just as the buds are opening will help materially to hold this pest in check, but this treatment is not advised unless the infestation is very serious. Observations would indicate that the pecan bud-moth never does sufficient damage in bearing orchards to warrant special spraying.

FIG. 31.—The pecan bud-moth: Larval injury to pecan foliage.

THE FALL WEBWORM.[1]

Perhaps the commonest insect coming under the observation of pecan growers is the so-called fall webworm, which constructs unsightly nests or webs over the twigs and foliage. These webs are more abundant during the late summer and fall, but since this insect has two generations in the South, the webs are to be found on pecan trees as early as May. Trees defoliated in late summer frequently develop leaves and flowers to the detriment of the crop the following year.

The moths (fig. 32), which usually are pure white but sometimes have black or brown spots on the forewings, emerge in the spring, during April and May. The eggs are deposited in masses on the leaves, are greenish white in color, and hatch in about a week (fig. 32). The larvæ are gregarious, and each colony forms a web in which all the caterpillars feed, eating the upper and lower surfaces of the leaves. When they need additional leaves for food they enlarge the web (fig. 33), which sometimes becomes very large and conspicuous.

[1] *Hyphantria cunea* Drury.

The full-grown larvæ (fig. 34) usually measure an inch in length and are covered with long white and black hairs arising from numerous tubercles. On reaching maturity they leave their webs and transform to brown pupæ in flimsy, hairy cocoons beneath rubbish on the ground, under the scales of bark, or just under the surface of loose soil. The earliest date for the emergence of moths of the second brood is June 26, but most of the moths of this generation do not appear until later. The second-brood larvæ have been found deserting their webs during the latter part of September, all through October, and occasionally as late as the first week in November, for the purpose of pupation. This insect passes the winter as pupæ, and moths appear the following year, during April and May.

FIG. 32.—The fall webworm (*Hyphantria cunea*): Moth and egg mass. Enlarged.

CONTROL MEASURES.

All webs containing caterpillars that can be reached conveniently should be removed and the larvæ destroyed. Sometimes burning the webs on the trees will be found practicable, but it should be done carefully, so that much of the foliage will not be scorched. A long-handled tree pruner can often be used to advantage in removing the webs that are well up in the trees. When the fall webworm is extremely abundant, as is the case in some years, the foregoing measures can be effective to a limited degree only. Pecan orchards sprayed for the pecan leaf case-bearer will suffer no material damage from this insect, as the same treatment will destroy these caterpillars as well as several other leaf feeders.

THE WALNUT CATERPILLAR.[1]

In the South branches of large pecan trees often are defoliated by colonies of a caterpillar which when full grown is black, with long whitish hairs, and nearly 2 inches in length. This is the so-called walnut, or pecan, caterpillar. When young it is brownish, with white stripes and somewhat more hairy than the matured

[1] *Datana integerrima* G. & R.

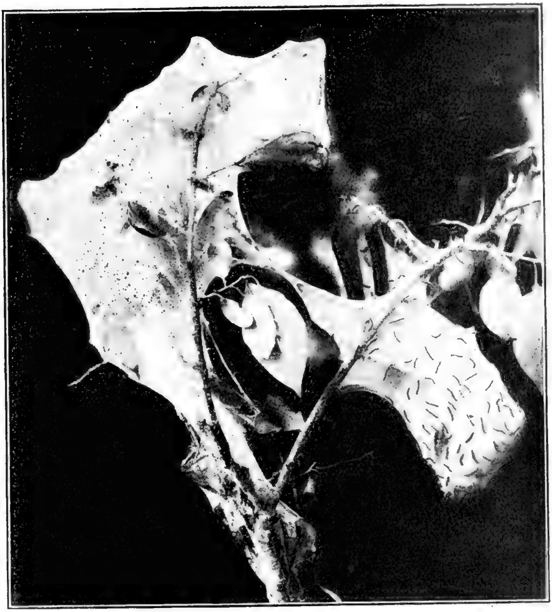

FIG. 33.—The fall webworm: Web and caterpillars.

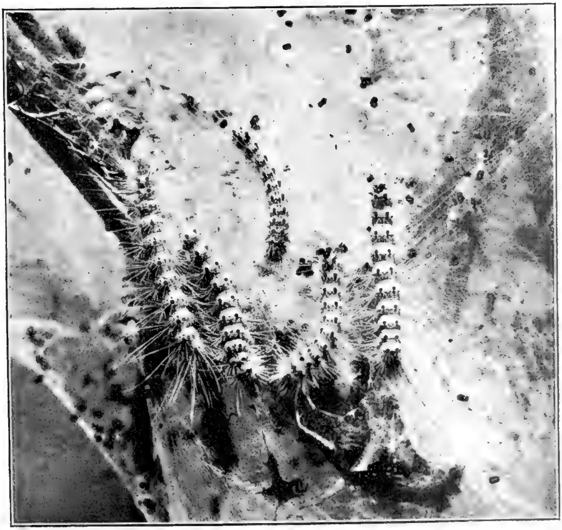

FIG. 34.—The fall webworm: Portion of web enlarged, showing larvæ.

larva. The larvæ upon hatching from eggs, which are deposited in masses (fig. 35) on the underside of the leaves, feed at first only on the underside of the leaflets, but later they devour the entire foliage except the stems and petioles. Small pecan trees, especially nursery stock, sometimes are defoliated completely, and it is not uncommon to see large branches on bearing trees stripped of their foliage. The larvæ feed in colonies (fig. 36), and in molting the larger caterpillars invariably leave their feeding place and crawl to the trunk or larger limbs, where in a mass they shed their skins, which may adhere to the bark for several weeks or longer. After molting they ascend the tree to continue their feeding depredations, and when fully grown crawl down the trunk and immediately enter the soil to a depth of a few inches. Here, in a day or two, pupation takes place.

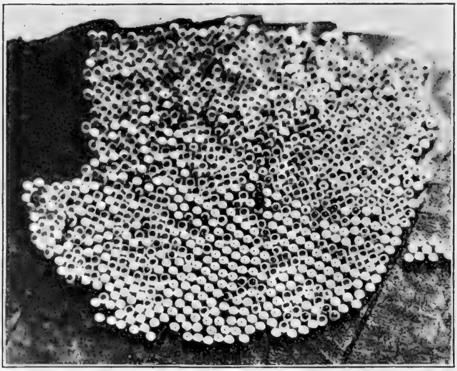

FIG. 35.—The walnut caterpillar (*Datana integerrima*): Egg mass. Enlarged.

In the North this insect has only one generation yearly, but evidently at least two generations occur in the South.

According to Bureau of Entomology records the moths (see fig. 37) developing from overwintering pupæ emerge from April 15 to July 15, and shortly after emergence egg laying takes place on the underside of the leaflets. The eggs, which are laid in masses usually numbering from about 100 to 150 each, hatch in a little less than a week and the larvæ feed for 25 days or longer before completing their growth. The caterpillars enter the soil to transform to brown pupæ, in which state they remain about 18 days for the summer generation. In the case of the fall generation the winter is passed as pupæ (fig. 38) in the ground and the moths do not emerge until the following spring or early summer. The second-brood larvæ enter the soil from the middle of September until the last week in October.

CONTROL MEASURES.

Whenever the egg masses or colonies of the caterpillars are discovered they should be destroyed promptly. Growers often may discover the larger larvæ massed on the tree trunks in the act of molting, and these should be destroyed by crushing or some other suitable means. Pecan orchards sprayed with arsenicals will rarely suffer serious damage by this insect.

FIG. 36.—The walnut caterpillar: Colony of larvæ on pecan.

THE HICKORY PHYLLOXERA.[1]

Pecan growers are alarmed occasionally by the presence of tumor-like swellings or galls (fig. 39) which sometimes occur on the leaves, leafstalks, and succulent shoots. These galls are caused by the attacks of an insect and are in no way to be associated with a disease organism, as seems to be a more or less prevalent notion among pecan growers. An examination of one of the newly matured galls will reveal the true culprit in both winged and wingless or immature forms. Before the maturity of the inhabitants the gall is closed, but by the time the inmates have acquired wings it cracks open, allowing the fully developed migrants or aphids to escape, and is left for the younger individuals.

The formation of galls is more pronounced during the early spring than at any other time, although galls may be found on the trees during the greater part of the growing season. Both the seedling and improved varieties of pecan are subjected to the attacks of these aphids, but it appears that injury is much more prevalent to the seedlings. It is not uncommon

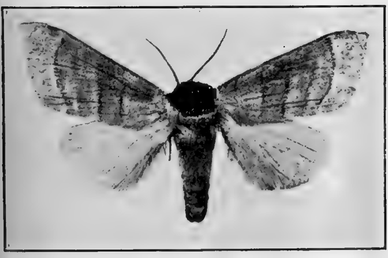

FIG. 37.—The walnut caterpillar: Adult, or moth. Slightly enlarged.

[1] *Phylloxera caryaecaulis* Fitch, and other species.

to find seedling nursery stock covered with galls, but budded or grafted pecan trees growing adjacent may, and usually do, escape injury.

Certain pecan trees in orchards are exceptionally subject to attacks by this insect, while trees growing immediately adjacent to the affected ones are not attacked and mature their full crop of nuts. Judging from the past behavior of the hickory phylloxera, it does not appear that this insect will be a very serious drawback to commercial production of improved varieties of the pecan under orchard conditions. This aphid attacks certain species of hickory as well as the pecan.

CONTROL MEASURES.

Under ordinary circumstances pecan trees slightly infested by this insect will hardly demand special remedial measures. Like many other insects, this species is subject to great fluctuation in numbers, and the amount of damage therefore will vary considerably from year to year. This variation in abundance is due to the fact that the insect is held more or less completely in check by natural enemies.

FIG. 38.—The walnut caterpillar: Pupa. Somewhat enlarged.

So far as present knowledge of this insect goes, no very satisfactory method of control can be employed during the growing season on trees that are so badly affected that the nut crop is seriously interfered with. It has been recommended that as many as possible of the badly affected leaves and shoots be clipped off by means of a 12-foot pruner before the galls open, and then burned immediately; but this treatment will hardly prove feasible for large trees. Perhaps the insect could be destroyed while in the egg stage, during the dormant season, by spraying with lime-sulphur solution, kerosene emulsion, or miscible oil; but so far no actual work along this line has been undertaken.

If certain varieties of pecans show an exceptional susceptibility to infestation year after year, top-working such trees with resistant sorts doubtless would prove a practicable means of avoiding injury by this species.

THE LITTLE HICKORY APHID.[1]

Often during the course of the season, especially in the spring and autumn, pecan foliage is seen to be infested by a little lemon-yellow aphid or plant-louse. This insect is commonly called the little hickory aphid, because it was first discovered feeding upon the hickory and because of its small size. Besides feeding upon the hickory

[1] *Monellia caryella* Fitch.

and pecan, it has been reported infesting the California black walnut [1] and hybrids derived from this tree.

About the time the buds on pecan are opening, the eggs of this aphid begin to hatch. Later the mature insects migrate to the unfolding foliage, upon which they feed by sucking the juice from the plant. They continue their feeding operations throughout the growing season, or until the trees shed their leaves. Throughout the spring and summer the non-sexual forms give birth to living young, but in the autumn (September and October) the sexual forms make their appearance on the trees and after mating the females deposit eggs on the twigs. These do not hatch until the following spring.

FIG. 39.—The hickory phylloxera (*Phylloxera* sp.): Galls on pecan.

Fortunately this insect does so little damage to pecan foliage that no special remedial measures are required. Its many natural enemies help much in keeping it in check. A significant feature about the infestation by this aphis is the abundance of "honeydew" excreted upon the foliage. Usually leaves covered by the sticky excretions support the growth of a black fungus which makes the foliage look unsightly and perhaps interferes to some extent with the proper respiratory action of the plant.

INSECTS INJURING THE TRUNK AND BRANCHES.

"WHITE ANTS," OR TERMITES.[2]

Pecan trees, as well as other kinds of plants, occasionally are injured and sometimes killed by attacks of the so-called white

[1] *Juglans californica.*

[2] *Leucotermes flavipes* Kollar is the most widespread and abundant species of termite in the Eastern States.

ants, or termites. Pecan growers in certain sections are familiar with these pests under the name "wood lice," the insects being so named because they often mine large galleries in dead wood and foundation timbers. On account of their underground habits and method of attack, termites usually escape detection until serious damage has been done, and are destroyed with great difficulty. The reports of injury to pecan trees have been confined for the most part to seedlings 1 or 2 years old growing on recently cleared land. Sometimes young budded and grafted pecan trees are injured or killed by termite attacks, but in most if not all cases the orchards were set out on new land containing an abundance of dead wood and humus.

As is the case with true ants, termites live in colonies, and because of their similarity to ants in appearance and habits the name "white ants" has come into more or less common usage. Termites only occasionally attack living trees, their principal and most serious damage being done to foundation timbers and woodwork of buildings. In cut-over woodlands they often are prevalent under the bark of dead logs or beneath the fragments of wood lying on the ground. On small seedling trees from 1 to 2 years old the taproot frequently is hollowed until little more than a shell of bark remains. (Fig. 40.) Termites usually gain entrance to the trees below ground, but their galleries may extend for an inch or so above the soil inside the heartwood. Apparently they attack grafted trees at the point where the graft has not healed over smoothly with the seedling stock.

The affected trees as a rule do not show any indication of injury until they are damaged beyond remedy, and then they die very quickly, as is shown by the sudden wilting of the leaves.

CONTROL MEASURES.

Because of the underground habits of termites it is difficult to apply a direct remedy to affected trees. Since they live in colonies and their nests usually are in the ground somewhere near the affected trees, it is important not only to kill the termites within the trees, but also to locate and destroy the inhabitants of the nests, in order that permanent results may be obtained. Nests perhaps can be destroyed best by pouring carbon disulphid into them and then immediately packing the soil around the nest. This is a volatile liquid, and the gas, being heavier than air, will penetrate all recesses of the nest and cause the destruction of the termites. Since carbon-disulphid treatment is somewhat dangerous to plant life, care should be employed not to use very large dosages around the trees. Sprinkling of tobacco dust in the nests and around the roots of affected trees has been reported to give good results, but the writer never has seen this treatment in practice, and therefore can not recommend its use with any degree of certainty as to its effectiveness.

The injury to pecan nursery stock will be most serious on recently cleared land where decaying wood is abundant, as termites show a decided preference for such wood as a breeding place. New land to be planted to nurseries should have all dead wood removed from the soil, and the growing of two or three farm crops on the land is advisable before planting the seedling nuts for the ultimate propagation of budded and grafted trees. As a nursery practice, for the prevention of attack by this insect, it is urged strongly that recently cleared land be avoided. The same advice holds true in case a young pecan orchard is to be set out, as prevention is a far more reliable method of fighting the pest than is the use of any direct remedy.

FIG. 40.—The white ant (*Leucotermes flavipes*): Injury to roots of pecan nursery stock.

THE OAK OR HICKORY COSSID.[1]

The oak or hickory cossid in its larval state inhabits the trunks or larger branches of pecan, hickory, and oaks, in which it bores or tunnels in the hard wood, making galleries several inches in length. The work of the larva is detected rather readily by the castings of wood that are distributed at the base of the tree trunks. A careful search of the affected trees will reveal the hole from which these castings are pushed out by the larva, in order that its larval gallery may be kept clear. When the larva is full grown, it considerably enlarges this hole, which is more or less oval in shape, and then transforms to pupa. Just before the adult insect is ready to emerge, the pupa wriggles its way to the mouth of its gallery, and upon the issuance of the moth the pupal case is left protruding a little from the exit hole.

[1] *Cossula magnifica* Strecker.

DESCRIPTION.

The moth (fig. 41) generally is gray, mottled with brown and black blotches, and has an expanse of wings of about one and three-fourths inches. Each forewing has a large, light brown patch, sprinkled at the end with dark-brown streaks. The hind wings are darker gray than the forewings and are without any markings. The head is brown, the thorax light gray, peppered with faint dark spots, and the abdomen brownish gray.

FIG. 41.—The oak or hickory cossid (*Cossula magnifica*). Adult, or moth. Very slightly enlarged.

The full-grown larva (fig. 42) is about $1\frac{1}{2}$ inches in length. The body is pinkish in general color and covered sparsely with short fine hairs which arise from the numerous tubercles. The head, cervical shield, or neck, and plates on the hind end of the body are shiny dark brown.

The pupa, to which the larva transforms upon attaining full growth, is generally brown, except the anterior part, which is blackish. On its head is a sharp projection which is of assistance to the pupa in pushing its way out of the larval burrow preparatory to the emergence of the adult moth.

FIG. 42.—The oak or hickory cossid: Larva. Enlarged.

SEASONAL HISTORY AND HABITS.

The complete life cycle of this insect is not known, but it probably occupies only one year in the extreme South, and longer in its northern distribution. The moths emerge usually during May and June, and lay their eggs shortly after their appearance. The larvæ upon hatching first attack small twigs, in which they tunnel out the center or pithy wood. (Fig. 43.) When the larva has grown too large for the small twig upon which it has been feeding, it crawls out and enters a larger limb. By the early fall the larvæ will be found attacking the tree trunks or very large lower branches, in which they bore into the hard wood and make their galleries parallel with the grain. At this time and during the spring months the grower can detect piles of pellets of frass or castings at the base of the trees, and this is a very good way to locate the insect in pecan orchards. The transformation to pupa takes place within the larval gallery during April or May. By means of the sharp toothlike protuberance on the head end the pupa wriggles along the tunnel to the exit hole, after which the skin splits open and the moth emerges.

CONTROL MEASURES.

All that can be done to control this insect in pecan orchards is to locate the larger limbs and tree trunks attacked, and destroy the larvæ by injecting small quantities of carbon disulphid into the holes, which should be stopped up immediately after treatment by means of putty, grafting wax, wooden pegs, or moist clay.

Fig. 43.—The oak or hickory cossid: Larval burrow in pecan twig. Enlarged.

THE FLAT-HEADED APPLE-TREE BORER.[1]

The flat-headed apple-tree borer has been known long as a more or less serious pest of certain fruit trees, such as the apple, quince, pear, peach, and apricot, and among its food plants are to be included several shade and forest trees. During the last few years this insect has been recognized in many sections of the pecan-growing belt as a serious enemy of pecan trees grown under orchard conditions, and in innumerable cases its larvæ have girdled and killed young trees. Its injuries are for the most part restricted to newly transplanted nursery trees and to trees that suffer from uncongenial soil or droughts, or are damaged by "barking" with cultivating implements. Pecan trees that have been affected by winter injury are very susceptible to the attacks of this borer. It is well known that pecan nursery stock does not stand transplanting so well as do many orchard fruit trees, as, for instance, the apple or peach, and perhaps this is because so much of the taproot is cut off in removing the trees from the nursery row. For the first year or two transplanted pecan nursery trees make little growth and do little more than establish themselves, even when the planting is done at what is considered the best time and with the utmost care. If the spring and summer following the setting out of the young trees are deficient in rainfall, the trees may be more or less seriously attacked by flat-headed borers, as the beetles seem to prefer to lay their eggs upon weakened or devitalized trees.

[1] *Chrysobothris femorata* Fab.

DESCRIPTION.

The beetle, as represented in figure 44, is oval and flattened and about one-half inch in length, but the size is somewhat variable. The antennæ, or "feelers," are short and toothlike, the eyes rather large, and each leg of the first pair is armed in front with a conspicuous tooth. The upper surface has a brownish metallic luster, the color of the underside is coppery bronze, and the part of the body underneath the wing covers is bright metallic greenish blue. The markings on the back, or wing covers, are well shown in the illustration.

FIG. 44.—The flat-headed apple-tree borer (*Chrysobothris femorata*): Parent beetle. Enlarged.

FIG. 45.—The flat-headed apple-tree borer: Larva in its burrow. Enlarged.

The larva (fig. 45) when full grown is about an inch long, without legs, and yellowish white. The second thoracic segment is much broadened and compressed, giving the larva the appearance of having a large flattened head. The larvæ within their galleries always assume a curved position, somewhat as is shown in the figure.

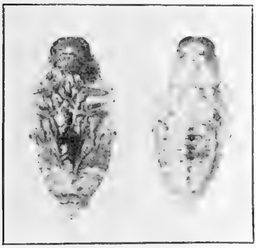

FIG. 46.—The flat-headed apple-tree borer: Pupa, ventral and dorsal views. Enlarged.

The pupa (fig. 46) is also yellowish white, somewhat more yellow than the larva, and it shows the undeveloped appendages and structures of the adult beetle.

SEASONAL HISTORY AND HABITS.

The beetles are to be found in pecan orchards from March to November, but they are especially abundant at two periods, namely, during May and from the middle of August until mid-

September. The beetles deposit their eggs in cracks or under bark scales upon the trunk or larger limbs. The young larva upon hatching gnaws through the bark and begins to feed upon the sapwood immediately beneath, making a more or less irregular gallery packed with sawdust castings, the gallery usually being evident through the bark. Some galleries have a very tortuous or spiral course (fig. 47), and because of this the affected trees are often girdled. If the trees are able to maintain considerable vitality in spite of the attacks, the larvæ do not enter the sapwood to transform to pupæ, as they do in dead and dying trees, but transformation to pupa takes place immediately under the bark, a slight excavation being made in the sapwood. One year is required for the complete development from egg to adult. Because of the different sizes of larvæ that may be found in trees at almost any season of the year, many growers believe that the insect has more than one brood. This, however, is to be explained by the great variation in rate of growth of the larvæ and the consequent variation in time of emergence of the beetles, this emergence taking place any time from March until early autumn.

FIG. 47.—The flat-headed apple-tree borer: Larval burrow in trunk of young pecan tree.

CONTROL MEASURES.

After borers have gained entrance to the trees nothing better can be done than to examine the trees carefully and remove the larvæ with a knife. The point of infestation on the trunk or limb usually can be detected by the discoloration and depression of the bark, which sometimes cracks open. In badly infested orchards the trees should be examined at least twice a year, and perhaps a third time would be advantageous. In cutting out "worms" great care should be taken not to cause any unnecessary injury to the trees, and the places from which the borers have been removed should be painted with white lead or some good tree paint.

Certain washes have been used with some little success for protection against this insect in apple orchards, but it is believed that this means of fighting the borer on pecan is impracticable. Since the beetles are to be found in pecan orchards from March until November, several applications of the wash would be required and the cost for the treatment would be excessive.

In pecan orchards the use of trap logs made from newly cut branches of any favorite host plant, in order to attract the adult beetles for egg deposition, may be found practicable, for it is well known that this insect prefers dead or dying wood to living trees. Perhaps oak would be the best and most available wood to be had for these logs, but hickory or pecan would serve the same purpose, as the borer breeds abundantly in all of them. These trap logs, from 4 to 6 feet in length and from 3 to 4 inches in diameter, should be placed at intervals of 100 feet or less during the late winter or very early spring. After these logs have been left in the orchard for one season they should be burned the following winter. The writer has captured hundreds of beetles on pecan and oak logs that were smeared with a viscous substance and placed in pecan orchards. This plan has not been tested on a large scale, but it promises to be of value, especially in badly infested orchards that have been neglected for some time and are adjacent to extensive woodlands.

Careful cultural methods are urged strongly as a measure of protection. All dead and dying trees and all pruned limbs or branches should be removed promptly and burned, for such wood affords an ideal breeding place for the borer and is therefore a menace to the orchard. The keeping of pecan wood about the orchard for future use as fuel or for other purposes is a bad orchard practice and can not be condemned too strongly. In several instances the writer has found large numbers of flat-headed borers in limbs and branches of pecan stored for firewood. In the transplanting of nursery stock to the orchard, every care should be taken to have the trees set out under the best conditions; and, judging from observations, early planting, say, in December and January, and not later than February, is to be recommended, so that the trees will get the benefit of the winter rains. As a measure of protection it is also essential that young trees be kept in a vigorous growing condition by frequent cultivation and the planting of tree rows to some suitable leguminous crop. The use of fertilizers also will help the trees to withstand attack by this species as well as by other wood-boring insects. It is important to remember that thrifty trees are less liable to attack than sickly or stunted ones and injury is best avoided by the maintenance of trees in a vigorous condition of growth.

THE RED-SHOULDERED SHOT-HOLE BORER.[1]

The red-shouldered shot-hole borer infests dead or dying pecan limbs, into which it bores for a considerable depth. The borings or frass of the larvæ are very fine and sawdust-like in appearance, and are firmly packed or compressed within the galleries, which run with the grain of the wood. Upon attaining full growth the larvæ pupate some time during the fall or spring, and the beetles emerge during the spring months. Beetles are sometimes found during the early winter in the larval galleries, in which they remain until warm weather begins. The beetles invariably make their way out at right angles to the larval galleries, and emerge through circular holes in the bark, as is shown in figure 48.

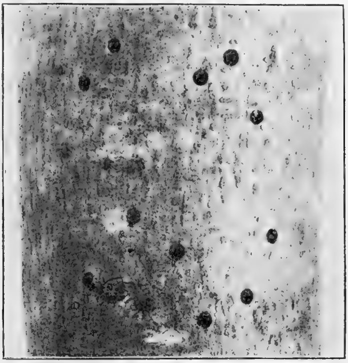

FIG. 48.—The red-shouldered shot-hole borer ([*Sinoxylon*] *Xylobiops basilaris*): Exit holes of adult beetles in pecan limb.

According to Mr. C. A. Reed, Nut Culturist in the Bureau of Plant Industry, trees so severely cut back for topworking or other purposes that the trunk becomes saturated with sap and the sap cells ruptured are fairly certain to become infested with shot-hole borers. It has been observed by some that not infrequently the borers are charged with being responsible for the unhealthy and apparently diseased condition of the tree, whereas actually the diseased condition of the trunk is responsible for the presence of the insects.

The beetle is black and has small punctures over the greater part of its body. The wing covers at the base or shoulder are reddish and at the tip or posterior end they are obliquely cut off, the edge of the cut being armed with three conspicuous teeth.

CONTROL MEASURES.

Since the insect attacks, as a rule, only dead or dying pecan wood, it is not to be considered a serious pest. Occasionally it attacks rather healthy trees, but it never causes any serious damage to them, since the larvæ can not subsist on wood containing a good flow of sap. As a protection against this insect, as well as against the more injurious wood-boring species, all dead trees and prunings should be removed from the orchard promptly and burned. Moreover, the trees should be kept in vigorous growing condition by practicing good orchard management.

[1] (*Sinoxylon*) *Xylobiops basilaris* Say.

THE BELTED CHION.[1]

The belted chion, in its larval state, attacks the pecan and hickories as well as other trees, forming long galleries in the trunk or limbs of weakened or dead trees. The galleries (fig. 49) are excavated to a considerable depth in the heartwood, in which they run in the same direction as the grain. The larva is a yellowish white, round-headed borer, with brown head and black jaws. Upon attaining its full development it changes to a pupa within its gallery and the adult beetle in emerging cuts a large circular exit hole through the bark (fig. 50). The beetles make their appearance any time from March to September, as has been determined from rearing records.

FIG. 49.—The belted chion (*Chion cinctus*): Larval galleries on pecan limb.

The size of the beetles varies, the length being from two-thirds to a little more than an inch, and in the males the antennæ, or feelers, are more than twice the length of the body. The color is light brown, usually with a short, oblique, dull band near the base of each wing cover, but in some specimens the bands are absent. Each wing cover bears two slender, conspicuous spines at its tip, and on each side of the thorax is a short, prominent spine. (See figs. 51 and 52.)

CONTROL MEASURES.

About all that is necessary to prevent injury to the pecan orchard from this pest is to remove dying trees or dead wood promptly and destroy the same by burning, as it is well known that this species prefers to breed in such material.

THE HICKORY TWIG-GIRDLER.[2]

The hickory twig-girdler is more or less familiar to all pecan growers and is an insect that is frequently the subject of inquiry. This spe-

[1] *Chion cinctus* Drury.

[2] *Oncideres cingulatus* Say.

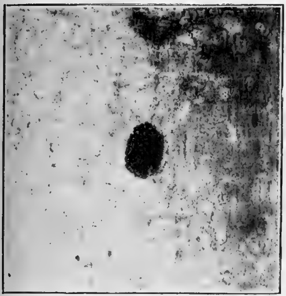

FIG. 50.—The belted chion: Exit hole of beetle.

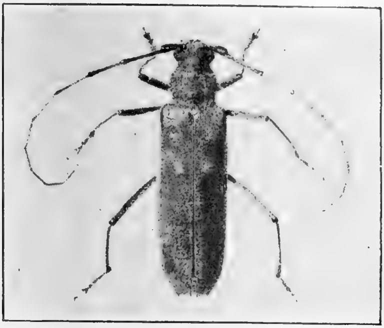

FIG. 51.—The belted chion: Adult female beetle. Enlarged.

FIG. 52.—The belted chion: Adult male beetle. Enlarged.

cies is accountable for the wholesale cutting off or pruning of pecan twigs, this injury being often conspicuous during the late summer and early fall. This beetle is found over a wide range of territory, occurring in most of the Eastern, Central, and Southern States, but in its more northern distribution the extent of its depredations is not very great. In the pecan-growing sections of the South it ranks as a first-class pest because of the excessive severing of branches from pecan orchard and nursery trees by the adult beetles. Besides attacking the pecan, this species has been reported as damaging the hickory, persimmon, oak, walnut, elm, maple, locust, linden, and various pome and stone fruits, including the apple, pear, quince, cherry, peach, and plum, as well as orange trees and rosebushes. In the South, however, it seems to confine its attacks, for the most part, to the pecan, hickory, and persimmon.

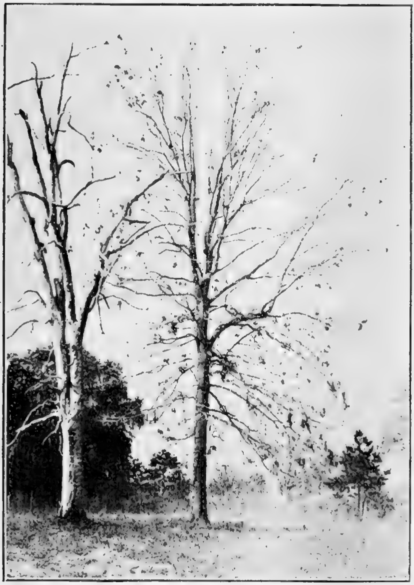

FIG. 53.—The hickory twig-girdler (*Oncideres cingulatus*): Bunches of cut-off twigs caught in branches of hickory tree.

When the beetles occur in abundance they are capable of doing much damage by severing branches for the purpose of egg-laying. It is not uncommon to see the ground under pecan or hickory trees literally covered with twigs that have been cut off by the beetles, and twigs often accumulate in the tree tops in conspicuous bunches (fig. 53). By the severance of the tips of the branches the fruiting area of the tree is greatly lessened or reduced and the nut crop indirectly affected for the following year, and perhaps for a longer period. This type of injury, besides affecting the nut production, causes the development of many offshoots, which destroy to some extent the symmetry of the tree. Pecan nurseries growing adjacent to a badly infested territory often suffer great loss from the girdling of the terminal branches of the nursery trees.

DESCRIPTION, SEASONAL HISTORY, AND HABITS.

The beetles (fig. 54; fig. 55, *a*) range in length from one-half to five-eighths of an inch, the female being larger and more robust than the male. They have long antennæ or feelers; those of the males are considerably longer than the body, but those of the female are only a trifle longer than the body. The body is subcylindrical, and the general color is grayish brown, there being a rather broad ashy band or belt extending over the middle of the wing covers. The thorax is about the same color as the ashy band, but the head is more or less reddish. Upon close inspection it will be observed that the wing covers are ornamented with many yellowish or straw-colored spots.

FIG. 54.—The hickory twig-girdler. Adult, or beetle. Enlarged.

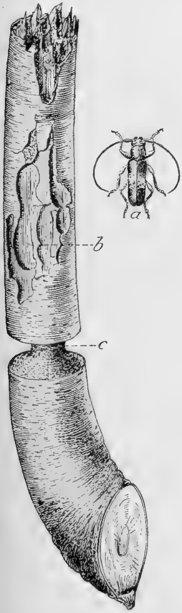

FIG. 55.—The hickory twig-girdler: *a*, Beetle; *b*, larval mines in bark and outer wood; *c*, girdling work of adult. (Webb.)

The eggs, which are always deposited in the severed branches, are white, elongate oval in shape, and about one-tenth of an inch in length.

The beetles, which begin to make their appearance in pecan orchards by the last of August or early in September, have very interesting habits. It is only the female of the species that cuts off the twigs, but both sexes feed more or less upon the tender bark and wood of the tips of the branches. The branches apparently are severed by the female in order that congenial conditions may be provided for the development of the larvæ, which are unable to subsist on wood containing sap, as has been determined definitely by field observations. It has been observed that the female in girdling does not make a complete circle at once, but cuts section by section until the entire twig has been girdled. The girdling extends through the bark and well into the wood, leaving only a narrow portion of the heartwood untouched. (See fig. 55, *c*.) Usually the weight of the branch, with the assistance of the wind, causes it to bend down or break off.

The eggs are laid during or after the cutting process, but never before the beetle has cut at least one section. They are inserted singly beneath the bark, or slightly into the wood, near a

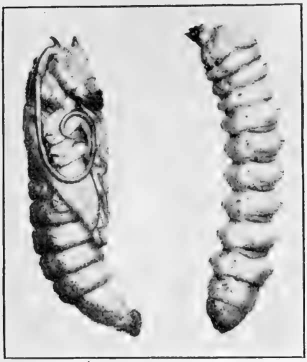

FIG. 56.—The hickory twig-girdler: Pupa at left, larva at right. Enlarged.

bud scar or adjacent to an offshoot. Usually they are deposited in the main stem of the branch, but if the branch is of a good size some eggs are to be found occasionally in offshoots. After the insertion of the eggs in the twig the puncture is sealed with a shiny, gummy substance, and the beetle then scars the twig for a short distance below the egg puncture. The number of eggs per twig may range from 3 to 40, although occasionally a severed branch without any eggs is found. The egg stage lasts about three weeks.

The larvæ (fig. 56, at right), which are whitish, legless grubs, make little growth during the fall or winter months, but with the advent of warm weather in the spring they grow very rapidly. In making their tunnels in the twig (fig. 55, *b*; fig. 57) they work usually toward the severed end and feed only on the woody fibers, leaving the bark intact. During the late spring or early summer most of the larvæ[1] make a few circular holes in the bark, from which they cast out pellets of frass and excrement. Just prior to transformation to pupa (fig. 56, at left) each larva closes the end of its gallery with shredded shavings, making the pupation quarters, from which the adult emerges by gnawing a more or less circular hole in the bark.

FIG. 57.—The hickory twig-girdler: Larval burrow in cut-off pecan twig.

[1] A few larvæ may not transform until the second season.

As stated before, the beetles begin to make their appearance in the pecan orchards about the last of August, and they may be found continuing their girdling operation until cold weather.

CONTROL MEASURES.

For the control of this pest all that is necessary is to gather the severed branches and burn them in the fall or winter. Care should be exercised to collect all branches from the ground, as well as those that may be lodged in the trees. By following this procedure all the eggs and larvæ which would otherwise develop into beetles the following summer will be destroyed, and thus the source of infestation will be eliminated. Pecan orchards that are growing adjacent to native hickory or persimmon trees will be found to be worst infested, because, as has been stated, this insect breeds abundantly in the severed branches of such trees. Under such conditions it would pay, perhaps, to destroy the branches cut from the hickory and persimmon trees immediately adjacent to commercial plantings of pecans.

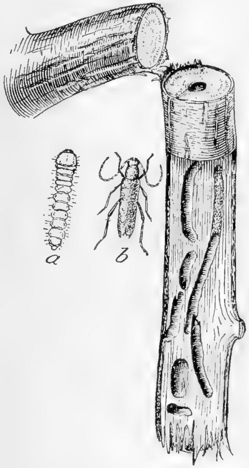

FIG. 58.—The oak pruner (*Elaphidion villosum*): *a*, Larva; *b*, adult; pruned twig and larval mines at right.

THE OAK PRUNER.[1]

During the fall and winter twigs or branches pruned by the larvæ or grubs of the dark-brown beetle known as the oak pruner (fig. 58) are to be found under pecan trees, as well as under oak, hickory, and various other forest, shade, and fruit trees. This insect does not especially favor the pecan, but seems to show a preference for various oaks. Although this insect occurs from New England westward to Michigan and southward to the Gulf States, it is seen too rarely in sufficient numbers in its extreme southern distribution to be ranked as a serious pest. In the North, however, serious injuries are sometimes caused by its pernicious pruning habits.

In the case of the pecan twig-girdler the twigs are cut off by the female beetle, but with the oak pruner the larvæ amputate the branches by gnawing a circular groove in the wood, leaving only the bark intact. The branches so amputated are usually brought to the ground by the first strong wind, or, in some instances no doubt, by the weight of the branch itself. The end of the severed branch presents a *smoothly cut* surface (see fig. 58), near the center of

[1] *Elaphidion villosum* Fab.

which will be seen a more or less oval opening plugged with fine shavings and sawdust. By way of contrast it may be stated that the end of the twig that is cut off by the pecan twig-girdler always presents at its center a more or less jagged surface.

In brief, the seasonal history is as follows: The beetles (see fig. 58, *b*) usually appear during the spring or early part of the summer, and the eggs are deposited in the leaf axils of the smaller twigs of living trees. Upon hatching, the larva feeds upon the wood immediately under the bark, but later it bores into the heartwood, where it makes an oval gallery several inches in length. (See fig. 58, at right.) In the fall it cuts away the wood at the end of its gallery in such a manner that the wind causes the twig to snap off. The larva (fig. 58, *a*) then proceeds to stop up the end of its channel with coarse shavings. In the larval burrow within the fallen branch the pupa is formed, either in the fall or early spring, and during the spring or early summer the beetle makes its appearance in the pecan orchards. Occasionally specimens of adults can be found in the pecan orchards as early as April.

CONTROL MEASURES.

The remedy for this species is the same as that for the pecan twig-girdler and consists in gathering the severed branches and burning them during the winter.

SCALE INSECTS.

Fortunately for the pecan grower it is seldom, if ever, necessary for him to spray his orchard trees for the control of scale insects, as is the common practice in the growing of apples, peaches, and other fruits. The pecan is not immune to attack by insects of this group, but because of the limited infestation scale insects have not up to this time (1917) come into the category of pests of first importance. When scale insects are found to be present on pecan trees specimens should be sent to the Bureau of Entomology for observation or to the State agricultural experiment station.

O

THE GIPSY MOTH AND THE BROWN-TAIL MOTH AND THEIR CONTROL

A. F. BURGESS
In Charge of Gipsy Moth and Brown-tail Moth Investigations

Female gipsy moths depositing eggs on tree trunk

FARMERS' BULLETIN 845

UNITED STATES DEPARTMENT OF AGRICULTURE

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

Washington, D. C. September, 1917

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THE GIPSY MOTH and the brown-tail moth are among the most serious and destructive of the insects injuring tree growth that have been introduced into the United States.

About one-third of the area of New England is now infested with these pests.

Marked progress in checking their spread has resulted from the field and quarantine work now being carried on and from the introduction of parasites and natural enemies, and the increase in the diseases that attack them has served to lessen the damage.

The work of combating these insects is being carried on by each of the New England States and by the United States Bureau of Entomology.

Hand methods generally employed against the gipsy moth are treatment of the egg clusters with creosote, banding the trees with burlap or a suitable tree-banding material, and spraying. These are described on pages 15-19.

Hand methods applicable against the brown-tail moth consist in cutting off and burning the winter webs before the caterpillars emerge in April and spraying with arsenate of lead, as described on pages 14-15, before the middle of August. Where the infestation is very slight the cutting and burning of the webs will be more satisfactory than spraying.

Orchards can be protected fully from these pests by a system of management that will cost very little in addition to the expense required for protection against other orchard insects. See pages 19-21.

The expense of caring for infested city and park trees is somewhat greater than for orchards, but practical measures can be adopted, as shown on page 21, and their cost will not be prohibitive.

The control of the gipsy moth and the brown-tail moth in forests is extremely difficult, owing to the relatively small amount of money that any owner can afford to expend in protecting his woodland. He should accept the advice of a State, local, or Federal official familiar with these insects and their control, who, after an examination, would be able to suggest the measures most applicable in the particular case. The general principles involved in woodland control of the brown-tail moth are explained on page 24, and those for the gipsy moth on pages 22-24.

THE GIPSY MOTH[1] AND THE BROWN-TAIL MOTH[2] AND THEIR CONTROL.

CONTENTS.

IN 1869 a number of egg clusters of the gipsy moth, an insect pest destructive 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. Valuable trees were lost and property values in that section depreciated.

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 for the protection of 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 appro-

[1] *Porthetria dispar* L. [2] *Euproctis chrysorrhoea* L.

priation was made by Congress for suppressing it, and the Secretary of Agriculture was authorized to take all possible measures to

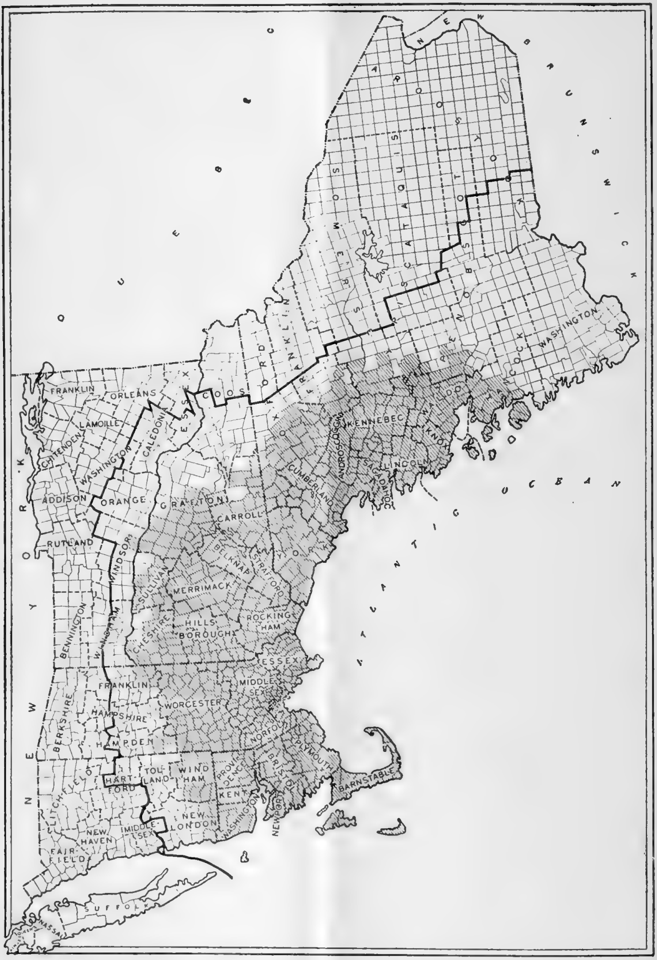

FIG. 1.—Map showing area infested by and quarantined for the gipsy moth and the brown-tail moth in New England, 1917. Shaded area infested by the gipsy moth; area east of heavy line infested by the brown-tail moth.

prevent its spread. Since that time work has been carried on each year. The area now known to be infested is shown in figure 1.

The brown-tail moth was first found in the United States in Somerville, Mass., during the summer of 1897 and was undoubtedly introduced several seasons before 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 often is seriously injurious. It spreads rapidly because the females are able to fly long distances. Figure 1 shows the area in New England which is now infested by the 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.

This bulletin describes briefly the seasonal history and habits of these two species and suggests the best methods for their control, determined and adopted as a result of many extensive experiments.

THE GIPSY MOTH.

SEASONAL HISTORY.

(Fig. 2.)

In the course of its life the gipsy moth passes through four stages—namely, the egg, the larva or caterpillar, the pupa or resting stage, and the adult or moth.

The eggs.—The female gipsy moth deposits a cluster containing 400 eggs or more, which she covers with buff-colored hairs. 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 stripped of foliage completely 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, with black wing markings, and flies well. The female is white, with black markings on the wings, and because of the weight of the abdomen does not fly. After mating the females begin depositing eggs.

MEANS BY WHICH THE GIPSY MOTH IS SPREAD.

Egg clusters of the gipsy moth that are deposited on trees, lumber, stone, or other products that are likely to be shipped may be carried long distances and cause the establishment of new colonies of the insect. Spread in this way is prevented by inspection of such products before they are shipped. Caterpillars of this insect may be spread for limited distances by carriage on moving objects, such as

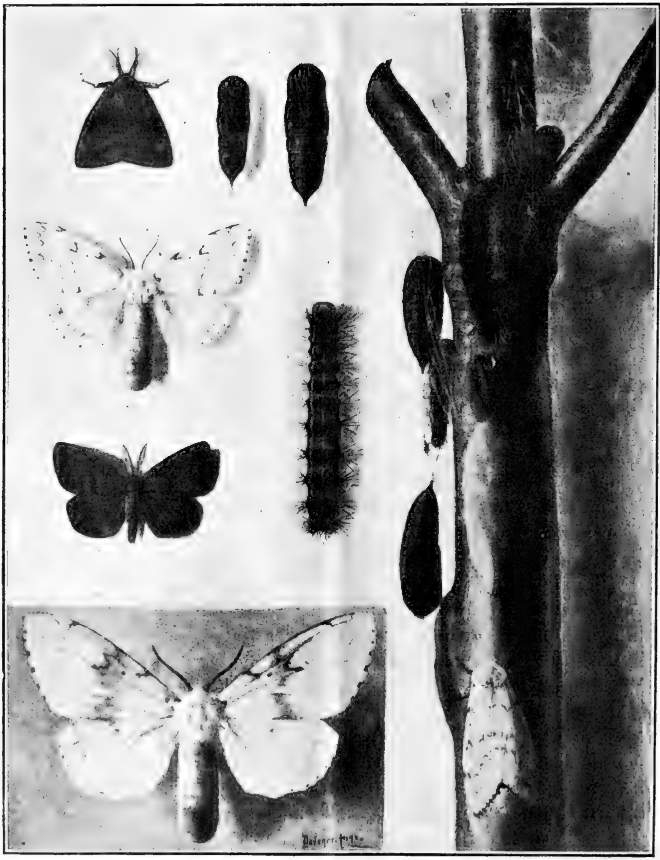

FIG. 2.—Different stages of the gipsy moth (*Porthetria dispar*): Egg mass on center of twig; female moth ovipositing just below; female moth below, at left, enlarged; male moth, somewhat reduced, immediately above; female moth immediately above, somewhat reduced; male moth with wings folded in upper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

trains, horse-drawn vehicles, or automobiles. The danger of such spread is very limited if the roadways are kept free from severe infestation, and under present conditions in the infested territory danger of spread in this way is not great. New colonies are started principally by the spread of newly hatched caterpillars. Experiments have shown that under favorable conditions these caterpillars may be blown by the wind. The temperature must be high enough for the caterpillars to be active and the stronger the wind the greater the probability of their being carried long distances. It has been demonstrated that caterpillars have been carried more than 20 miles in this way, and specimens have been caught in the air 50 feet above the ground, although probably they are carried much higher than this. It is necessary for the temperature to range above 65° F. and for the wind velocity to be 8 miles or more per hour, in order that wind spread of small caterpillars may result.

FOOD PLANTS.

The food plants most favored by the gipsy moth are the apple, the different species of oak, gray birch, alder, and willow. In cases of bad infestation nearly all 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.) Many areas were cut before the trees were mature and the wood sold at a loss on account of damage caused by this insect. 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 weakened severely 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 most damage in this way is a beetle[1] known as the two-lined chestnut borer, the larva of which feeds beneath the bark of injured trees.

[1] *Agrilus bilineatus* Weber.

NATIVE ENEMIES.

Few insect enemies of the gipsy moth native to New England cause any noticeable reduction in 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

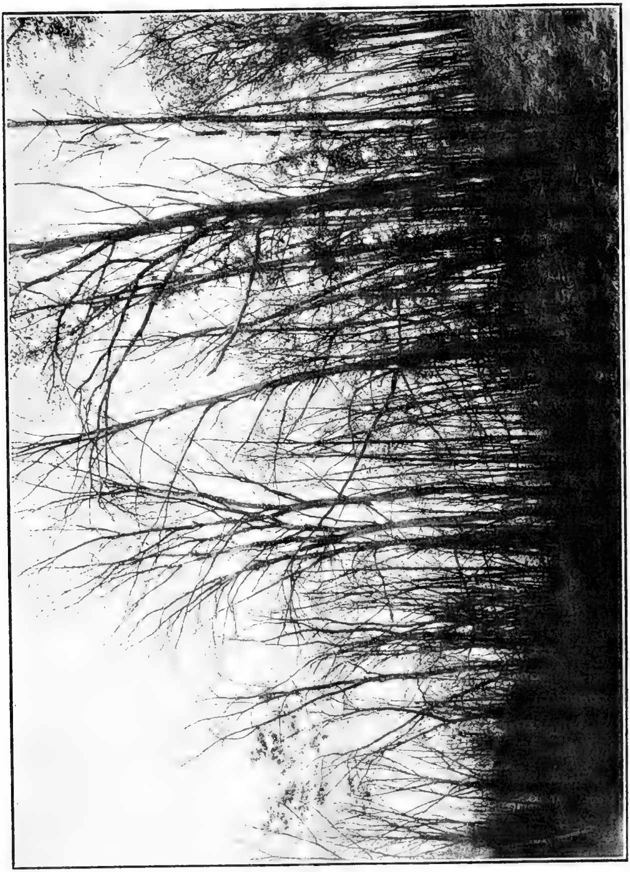

FIG. 3.—Dead and defoliated woodland resulting from gipsy-moth attack.

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, however, which possibly may have occurred in this country for many years, has become sufficiently prevalent 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 and as a result several natural enemies have become firmly established in this country and are assisting in bringing about the control of the species. The enemies which have become established and are at present destroying the largest number of gipsy-moth caterpillars and pupæ are a beetle,[1] a tachinid fly,[2] which is also a parasite of the brown-tail moth and attacks many native injurious caterpillars; and a minute four-winged wasplike parasite,[3] which attacks small gipsy-moth and small brown-tail moth caterpillars. Two tiny parasites of the eggs, one of which[4] was imported from Japan and the other[5] 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. Several other parasites have been introduced and are established in this country, but they have not increased sufficiently to be classed as important factors in gipsy-moth control.

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 larger numbers over the entire infested territory the insect will be much less a destructive factor than it is at present. Colonization of most of these species has been carried on throughout the entire area but much remains to be done in colonizing the egg parasites. The records at the gipsy moth laboratory at Melrose Highlands, Mass., indicate that all of the species of insect parasites mentioned have been gradually increasing in the field during the past few years and the results of their work are very noticeable in certain restricted areas. Until these natural enemies become more abundant than they are at present throughout the entire infested territory it will be necessary to employ the most effective mechanical methods for restricting the spread and curtailing the increase of this species.

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[1] *Calosoma sycophanta* L.
[2] *Compsilura concinnata* Meig.
[3] *Apanteles lacteicolor* Vier.
[4] *Schedius kuanae* How.
[5] *Anastatus bifasciatus* Fonsc.

THE BROWN-TAIL MOTH.

SEASONAL HISTORY.

(Fig. 4.)

As is the case with all other moths, the brown-tail moth in its development is first an egg, then a larva or caterpillar, then a pupa, and finally an adult moth.

The eggs.—The female brown-tail moth deposits a small cluster of eggs on the underside of a leaf. These eggs usually are laid in July and are covered with brown hairs 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 sometimes are constructed separately, but in many cases large numbers of them are spun in a single mass. About two weeks are spent in the pupa state.

The adults.—Emergence of the moth usually begins the first week in July. The adult brown-tail moth is pure white. 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 sometimes they are found in considerable 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 often are 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 often is checked severely. In heavy infestations trees may be stripped completely (figs. 5, 6), but as the larvæ become full-grown during the first part of June, the trees usually have an opportunity to refoliate before midsummer. The young larvæ that hatch in August frequently skeletonize the leaves

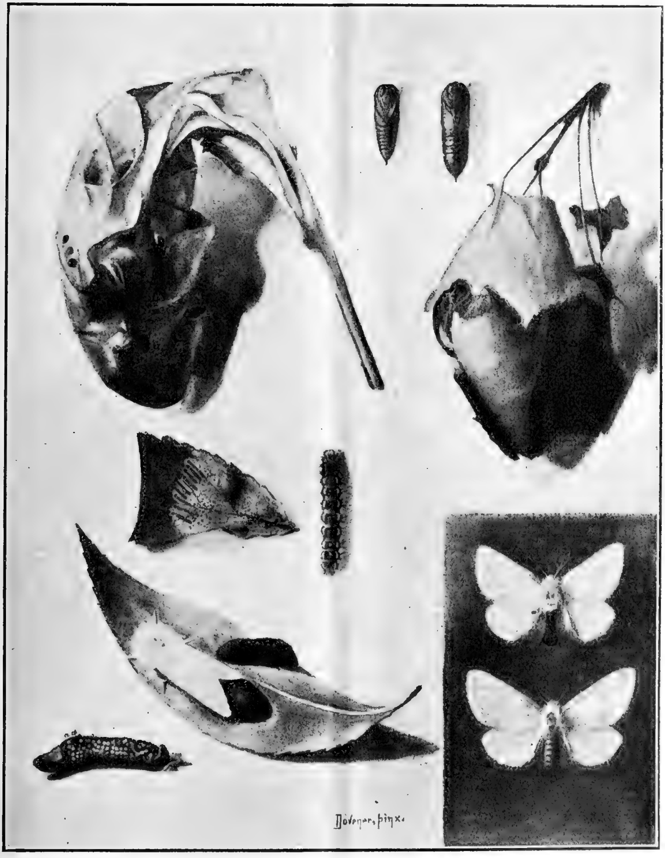

FIG. 4.—Different stages of the brown-tail moth (*Euproctis chrysorrhoea*): Winter nest at upper left; male and female adults, lower right; cocoon in leaves, upper right; male and female chrysalides above, male at left; full-grown larva in center, somewhat reduced; young larvæ at its left; egg mass removed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

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 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. Persons differ considerably in their susceptibility to this poison, but many cases are reported each year in the infested region, most of which are more

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

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.

NATIVE ENEMIES.

One of the most important natural enemies of the brown-tail moth is a fungous disease,[1] which attacks the caterpillars, particularly in the spring. It was first reported in this country by Dr. Roland

[1] *Entomophthora aulicae.*

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, under the most favorable conditions,

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

may be almost completely exterminated. Native parasites and predacious 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, with the exception of the egg parasites, also attack the brown-tail moth. The Calosoma beetle[1] and its larvæ do valuable work each year in destroying brown-tail caterpillars and pupæ, and the insect parasites also attack this species in considerable numbers. Another imported parasite[2] has become established in this country and is doing excellent work. It attacks the brown-tail moth caterpillars, but not those of the gipsy moth.

Throughout the infested territory a marked decrease in the number of moths has been noted during the last two or three years. The work of the parasites has been a very important factor in this connection. In some parts of the infested territory the mortality among the caterpillars in the brown-tail webs has been very high during the winter.

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

[1] *Calosoma sycophanta* L. [2] *Meteorus versicolor* Wesm.

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 sprayed it is practicable to wipe the fruit before packing for sale; but this will not be 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 material is sold by dealers in the infested region under the name of gipsy-moth creosote. It is applied with a brush, and 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.

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 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 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 furnished 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 moth caterpillars will have pupated.

Sticky bands.—Bands of a widely known sticky substance for use in banding trees, which may be obtained on the market, may be used on tree trunks after the bark has been scraped so that the 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 previously have 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 caterpillars usually mass in large numbers beneath the bands, conditions are favorable for the development of wilt disease, and the caterpillars often die in large numbers from this cause and from starvation.

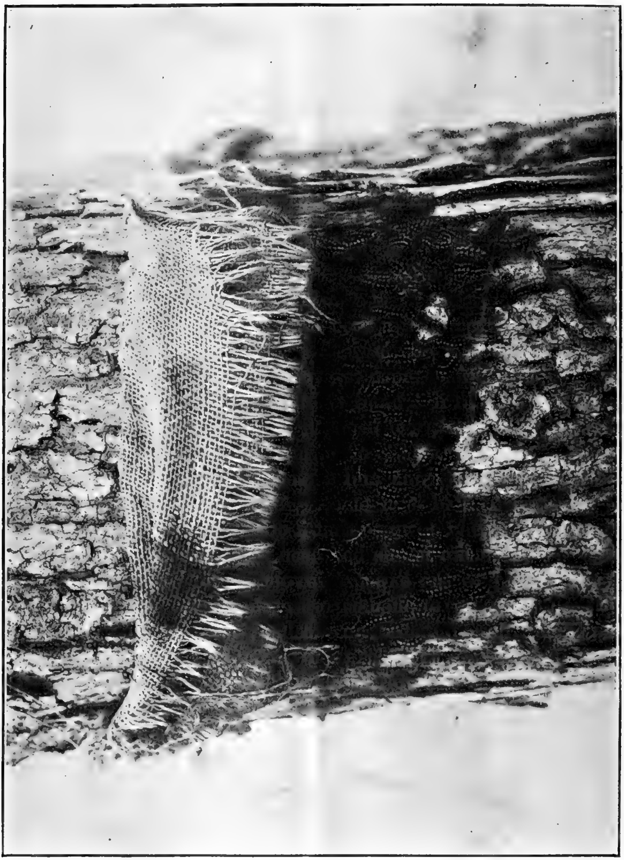

FIG. 7.—Burlap band on tree. The caterpillars beneath it are nearly all these of the brown-tail moth.

Use of tree-banding material.—A new material for banding trees has been prepared and tested by the Bureau of Entomology in cooperation with the Bureau of Chemistry. It is black and of a greasy nature and is applied to the trees with a special "gun" designed for the purpose. (Fig. 9.) A thick, narrow band is left on the tree trunk, preventing the caterpillars from reaching the foliage. This material is cheap and effective and is more easily applied than is the sticky substance mentioned in the last paragraph, because it is not necessary to scrape the trees before it is put on.

FIG. 8.—Band of sticky material. Note that the enormous numbers of gipsy-moth caterpillars are below the band, but none are above it.

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. 11.) With such a sprayer it

FIG. 9.—Applying tree-banding material to protect the foliage from gipsy-moth caterpillars.

is unnecessary to climb trees and use small lines of hose, which is a slow and expensive operation. A satisfactory high-power sprayer (Fig. 10) 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 225 to 350 pounds. This machinery, together with a 400-gallon tank, should be mounted on well-built trucks. One-inch hose is used, and by slightly increasing the pressure at the machine the spray material can be conducted through several hundred feet of this hose with the outfit mentioned without seriously reducing the nozzle pressure, which should be maintained at about 225 pounds.

By using a small device, which is attached to the nozzle and is known as a spreader, it is possible to spray low growth very satisfactorily. Fruit trees can be treated very rapidly in this way (Fig. 12).

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 determined largely by 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 have fallen, will be found useful, providing the amount of poison used is increased to 10 pounds 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 probably will be necessary to creosote egg clusters in the winter and

FIG. 10.—High-power sprayer.

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 the sticky substance previously mentioned or with the new tree-banding

FIG. 11.—Spraying trees 85 feet high with high-power sprayer. Note thorough distribution of poison on plate (9) located at top of tree. (Worthley.)

material referred to on pages 16 and 17. 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 for protection 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

FIG. 12.—Spraying orchard with solid stream, using spreader. (Worthley.)

instances it probably would be advisable to use bands and to discontinue spraying, especially in cases where the infestation is light or moderate. If the infestation is bad, creosoting, banding, and spraying all should be used in their season, in order that the insect may be brought under control and the numbers present reduced 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 already have 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 studied carefully 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. 13.) 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 considered carefully before a decision is reached as to the best methods of treatment. Sometimes practical methods of thinning can be adopted so that tree 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 reduce greatly the chance that the sprout growth will be replaced by any species of value that can withstand gipsy-moth attack. This problem

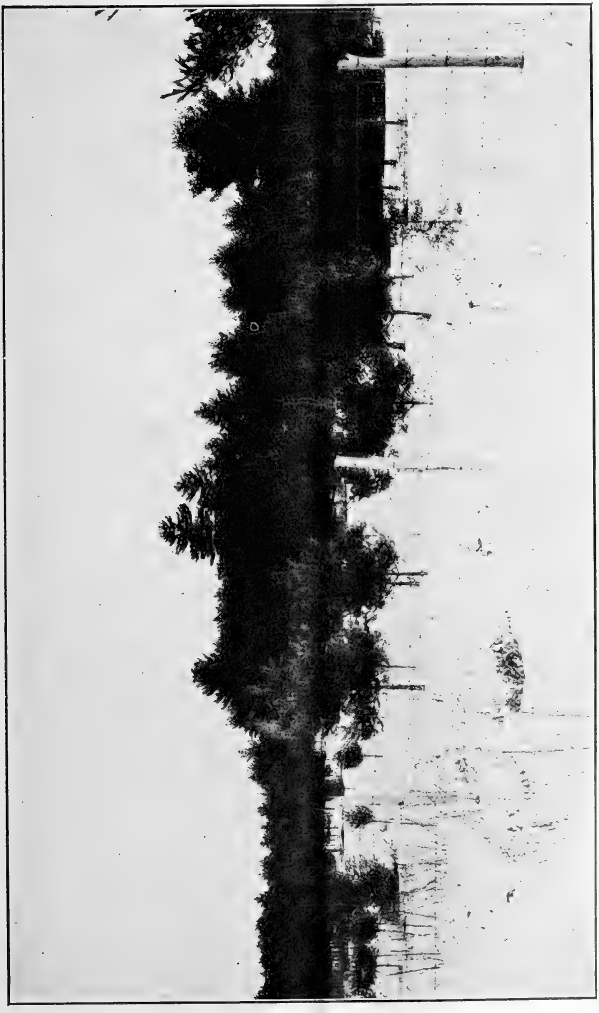

FIG. 13.—Solid white-pine block near Nashua, N. H.: Small trees in foreground were transplanted some years ago. The foliage of this species is not attacked by *small* gipsy-moth larvæ, so it is not injured if grown in clean stands.

is being specially studied and considered in the hope that some economical method may be devised for protecting and improving woodlots of this character at moderate expense. It is true that in considerable areas of oak woodland 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 cut promptly 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 done to advantage, but as this involves 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 woodlot in this way must in the end be decided by the owner of the property.

The presence of the chestnut-bark disease or the white-pine blister rust in a locality should receive due consideration before plans are made for planting or encouraging the growth of either of these species.

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 ordinarily is 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, therefore, is increased greatly. 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 because of local conditions, but the same general methods of field work are employed.

In Maine the work is in charge of the commissioner of agriculture, who has authority to appoint a superintendent of moth work. The southwestern portion of the State is from generally to badly infested with the gipsy moth, while in the outlying area only scattering infestations have been found. The brown-tail moth usually is most abundant along the coast or near the main water courses. Seven thousand six hundred and fourteen square miles in this State are infested with the gipsy moth and 16,783 square miles with the brown-tail moth.

In New Hampshire the moth work is in charge of the State entomologist. Five thousand nine hundred and twenty square miles are infested with the gipsy moth and 8,113 square miles with the brown-tail moth. The heaviest gipsy-moth infestations in the State are south of Lake Winnepesaukee, although extensive infested areas occur west of the Merrimac River.

In Vermont the moth work is in charge of the commissioner of agriculture, who appoints a deputy to carry on the field work. Only one town in this State has a gipsy-moth infestation and this consists of a few eggs clusters which have been treated and the locality cared for by employees of the Bureau of Entomology. The whole area known to be infested by the brown-tail moth amounts to 2,666 square miles, but the infestation is very light and in many of the towns within this area it is very difficult to find this insect.

The State forester has charge of the moth work in Massachusetts. Each infested town is required by law to select a local superintendent, whose appointment must be approved by the State forester. Owners are required by law to keep their property free from these pests, but can not be compelled to expend for this purpose more than $5 on each $1,000 assessed valuation. Town and city appropriations are made to give proper treatment to the street trees and those in public parks, and if sufficient funds are not available to do the work properly, financial aid is given by the State. The gipsy moth infested area in Massachusetts covers 4,980 square miles and 6,115 square miles are infested to a greater or less extent by the brown-tail moth.

The 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. Every town in the State is infested with both of these pests. The insects are most abundant in the northern part of the State and in the territory immediately surrounding Providence.

In Connecticut the work is in charge of the State entomologist. The brown-tail moth infestation covers 1,993 square miles and the gipsy-moth infestation 639 square miles. There is great danger that the gipsy moth will spread rapidly in this State, owing to the fact that the oak, which is a food plant favored by this insect, is one of the predominating trees.

The small colony of the gipsy moth which was found in Geneva, N. Y., in 1912 has been exterminated. Effective work was done by the State department of agriculture, and several inspections of the colony and its surroundings have been made by employees of the Bureau of Entomology. The colony located at Mount Kisco, Westchester County, N. Y., in May, 1914, has been treated thoroughly and no egg clusters have been found during the past year. Persistent work has been done in an attempt to stamp out this colony, both by the State and by the Bureau of Entomology, and it is hoped that this may be accomplished after another season's work.

In February, 1914, a colony was reported on an estate at Bratenahl, near Cleveland, Ohio. The territory was scouted thoroughly by employees of the Bureau of Entomology and treatment applied by the State nursery inspector. No infestation has been found in the colony or its surroundings for more than a year, and it is believed that the insect is exterminated.

A small colony was found at Rutherford, N. J., in July, 1914. It has received careful attention and as a result of the work done has been exterminated.

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 by hand measures to prevent the spread of this species, 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. All the principal infestations found in new territory have been along the line of the winds prevailing when the gipsy-moth caterpillars are hatching in the spring. The greatest danger of spread is toward the north and northeast, as the warm winds in the spring, particularly along the coast, are from the south and southwest. In New Hampshire, between the Merrimac and Connecticut Rivers, and in the infested region south of it, extending through Massachusetts, Rhode Island, and Connecticut to Long Island Sound, the problem of wind spread has the greatest bearing on the further dispersion of the gipsy moth. Scouting and extermination work is carried on extensively in this region under the direction of Mr. L. H. Worthley and every effort is being made not only to determine whether infestations exist in the new territory, but to exterminate the insects in several tiers of towns adjoining the border in order that wind spread into the territory that already has been treated may be prevented.

In town or city work the bureau advises that careful attention be given to woodland infestation or isolated trees, particularly if they are located on high elevations immediately outside the residential area, as such colonies may furnish a supply of caterpillars which will be distributed throughout the town after it has been cleaned.

Under present conditions, owing to the decrease in the severity of gipsy-moth infestation in most sections, spraying becomes an economical means of treatment and in some cases is used exclusively for control.

A great amount of experimental work has been conducted in order that better methods of controlling these insects may be determined. The introduction of natural enemies from Europe and Japan has proceeded systematically and good results are being noted in many localities. A systematic study of the wilt disease, which attacks gipsy-moth caterpillars in the field, is being made in cooperation with the Bussey Institution of Harvard University. Silvicultural investigations, which have for their purpose the adoption of better methods of forest management which will assist in the control of these pests, are being carried on in cooperation with the Forest Service of this department. This work is conducted by Mr. George E. Clement.

The entire infested area—20,211 square miles occupied by the gipsy moth and 36,684 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 and stone and quarry 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.

COOPERATIVE WORK.

Since the gipsy moth and brown-tail moth work was started by the Bureau of Entomology more or less cooperative work has been carried on with the States concerned. The introduction of parasites and natural enemies of the gipsy moth was conducted cooperatively with the State of Massachusetts for several years. After the infestation covered large areas in other States an arrangement was made for this work to be carried on by the Bureau of Entomology. The general plan of field work is for the bureau to handle the territory embracing several tiers of towns along the outside border of gipsy-moth infestation, while the States manage the work inside this area. The quarantine covers the entire infested area, while the experimental work, including the colonization of parasites, is being carried out in a systematic way for the purpose of developing better methods for the use of all concerned and to bring about the dispersion of the various parasites over the entire infested area as rapidly as possible.

THE OUTLOOK.

Infestation by the brown-tail moth is less severe than it has been for a number of years. A marked reduction in the number of winter webs has been noted, and if natural enemies continue as effective as they are at present, this insect can be controlled with small expense. At the present time, however, there is no way of telling exactly what will happen in this respect, and a careful record is being kept as to the abundance of this insect so that more work can be done upon it if the effectiveness of natural enemies should be suddenly reduced.

The gipsy-moth infestations have been reduced considerably during the last few years. The territory infested has remained practically the same and the improved methods which have been employed have shown good results. The great danger that widespread infestation will be brought about by wind drift of the small caterpillars can not be ignored and every effort is being made to restrict this danger as much as possible. When parasites are becoming more effective, and the increase of the gipsy moth in the field is slow, is the proper time to exert every effort to reduce further the abundance of the insect and so far as possible decrease the area infested.

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THE TOBACCO BEETLE AND HOW TO PREVENT DAMAGE BY IT

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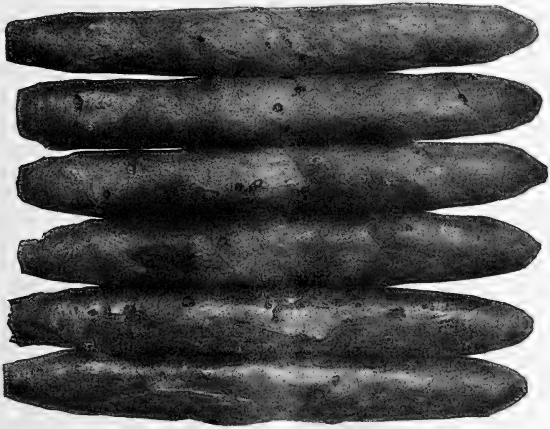

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UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology
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THE TOBACCO BEETLE is a reddish-yellow or brownish-red beetle, about one-tenth of an inch long, the larva of which attacks cured tobacco and tobacco products, riddling them with its tunnels and rendering them unfit for use. It is found in practically all countries and occurs wherever large quantities of leaf or manufactured tobacco are handled or stored. It does not attack growing tobacco.

The more important methods of preventing losses from the tobacco beetle may be summarized as follows:

Scrupulous cleanliness in the factory or wholesale or retail establishment, including the prompt destruction or treatment of all refuse material, damaged stock, etc., in which the beetles may breed.

Screening or otherwise protecting the finished product from infestation.

Constructing or refitting packing or storage rooms, especially in warm localities, so that they will be free from hiding places for the beetles and can be cleaned quickly and easily, and so that beetles which may be present in other parts of the building will be excluded.

Among destructive agencies which may be employed in control of the insect are:

Freezing. (Treatment by cold storage or, in cold climates, by exposure to low temperatures.)

High temperatures or steam. (A temperature of from 125° to 140° F. continued for several hours, or 150° for a short time, kills all stages of the insect.)

Trapping or destruction by mechanical means.

Fumigation with carbon disulphid or hydrocyanic-acid gas.

The modern practice of storing leaf tobacco in hogsheads in specially constructed buildings or sheds, giving practically out-of-door conditions and variations of temperature, furnishes, in cool climates, an effective means of reducing or preventing injury to the classes of leaf tobacco which may be stored in this manner.

THE TOBACCO BEETLE[1] AND HOW TO PREVENT DAMAGE BY IT.

CONTENTS.

MOST tobacco dealers and manufacturers are more or less familiar with the tobacco or "cigarette" beetle. This small beetle is an indoor species, is the most widely distributed of all insects affecting tobacco, and is one of the worst pests of the tobacco industry. Usually it is present in some stage at all times in practically all tobacco warehouses, cigar and tobacco factories, and extensive wholesale or retail establishments. It lives within its food substance during all stages of its existence. For this reason it is spread easily, and its capacity for injury is large. With tobacco, as well as with its other food substances, of which it has a variety, the actual quantity consumed is usually of far less importance than the presence of refuse, dust, dead bodies of the beetles, etc., which soil the manufactured product or make it unsalable and worthless. In a valuable product like fine leaf tobacco used as wrapper, or in expensive cigars or cigarettes, a very few beetles are capable of causing serious damage in a very short time. (See illustration on title-page.)

LOSSES DUE TO THE TOBACCO BEETLE.

Losses occasioned by the tobacco beetle, either directly or indirectly, occur wherever tobacco or tobacco products are handled. Statements received from manufacturers show that the loss at the factories is large, estimates from some of the larger concerns ranging from $5,000 to $25,000 per year. This, however, probably represents only a small part of the loss from damage to cigars, cigarettes, and manufactured tobacco in the hands of the jobbers and retailers. A heavy loss also occurs from damage to leaf tobacco, but it is difficult or impossible to obtain even an approximate estimate of the total loss.

[1] *Lasioderma serricorne* Fabricius; order Coleoptera, family Ptinidae.

FIG. 1.—Chewing tobacco injured by the tobacco beetle (*Lasioderma serricorne.*)

CHARACTER OF INJURY.

Injury by the tobacco beetle is almost entirely the work of the larvæ, or young. The adults, or beetles, do not seem to injure tobacco directly in any way except when burrowing out after transforming from the pupa or resting stage.

This insect damages cigars and pressed tobacco by eating out or burrowing small cylindrical tunnels and leaving them filled with a mass of dust and excrement. In cigars the holes sometimes extend straight through from one side to the other; in other instances they wind about through the filler of the cigar so that a large part of the interior is destroyed without much evidence of injury showing on the wrapper. The larvæ often work between two closely packed cigars, slitting the wrapper lengthwise for some distance. In a box or package a single larva may injure several cigars. The pupal cells frequently show between closely pressed cigars or on the edge of the band. Dust and refuse from feeding collect in the bottom of the box and between the cigars. Injured cigars do not draw well and burn unevenly, and dust is drawn into the mouth of the smoker.

In cigarettes holes are bored through the wrappers and frequently through the cork tips. The interior of the cigarette is filled with refuse, and the wrapper becomes soiled and discolored. Injury is more likely to occur in cigarettes made from the sweeter, milder types of leaf, such as are used in the more expensive grades. Fine Turkish tobaccos are especially liable to infestation.

Smoking and chewing tobaccos often become badly worm-eaten (fig. 1). In the pressed kinds galleries are formed, and in chewing tobacco the wrapper is cut and the edges furrowed (fig. 2). Granulated and fine-cut tobaccos become mixed with the dust and refuse from feeding and with dead bodies of the adults. Pupal cells occur on the sides of the container or in the tobacco. Holes are found in the paper or tin-foil wrapping.

Leaf tobacco is affected in much the same manner as cigars (fig. 3). The larvæ bore holes in every direction through the leaves, and the tobacco becomes soiled with dust and refuse. Fine wrapper becomes worthless. In leaf tobacco used for filler, for manufactured tobacco, or for snuff, the damage is confined more to the tobacco actually consumed by the larvæ than it is in the manufactured products, the mere sign of infestation making the finished product unsalable and worthless.

DESCRIPTION OF THE INSECT IN ITS DIFFERENT STAGES.

The egg.—The egg of the tobacco beetle is a small, pearly white, oval object about one-fiftieth of an inch in length. Owing to its small size and to the fact that commonly it is laid in creases or folds of the leaf, it is not seen readily, and to many persons familiar with the other stages of the insect is an unfamiliar object.

The larva, or grub.—The larva, grub, or worm stage of the insect is most likely to be noticed in infested material. The larva when

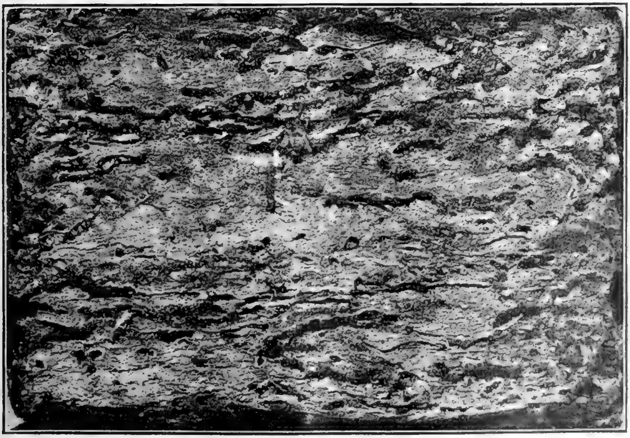

FIG. 2.—Pressed cut smoking tobacco showing burrows of larvæ and exit holes of adults of the tobacco beetle.

fully grown (fig. 4, *a*) is about one-sixth of an inch in length and yellowish white in color. It is fleshy and grublike in appearance and usually lies in a curved position. The head is pale brown and the body is covered with long, silky, yellowish-brown hairs, to which particles of the food substance or refuse adhere, giving the larva a somewhat dusty or dirty appearance. The legs are short and pale

FIG. 3.—Cigar tobacco showing work of the tobacco beetle.

brown. When newly hatched from the egg the larva is very minute, being only about one-fiftieth of an inch in length, and is more active than when more fully grown.

The pupa.—The pupa (fig. 4, *b*) is an inactive or quiescent stage which the insect assumes before transforming to the adult, or beetle. The pupa period is passed normally within a closed cell composed of small particles of the food substance and refuse cemented together with a secretion of the larva. The pupa is about one-seventh of an inch in length. It is white when first transformed from the larva stage, but before becoming adult it gradually assumes a brownish tinge, the eyes becoming reddish or reddish brown. It lies on its back in the pupal cell. Should the cell be broken open and the

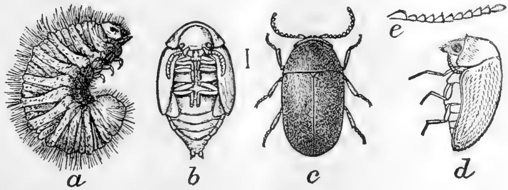

FIG. 4.—Tobacco beetle: *a*, Larva; *b*, pupa; *c*, adult; *d*, side view of adult; *e*, antenna. *a–d*, Greatly enlarged; *e*, still more enlarged. (Chittenden.)

pupa removed, transformation is completed in an apparently normal manner, providing the pupa is protected from rapid evaporation. When infested leaf tobacco is handled, many bare pupæ may be seen which have been dislodged from the fragile cells or cocoons between the leaves of tobacco.

The adult, or beetle.—The beetle (fig. 4, *c–e*) is the fully developed, or adult, stage of the insect. It is uniformly dull reddish yellow or brownish red. The head is broad and the eyes are small. The head is bent down nearly at right angles with the body, giving the beetle, when viewed from the side, a characteristic humped appearance. The beetles vary greatly in size, the average length being about one-tenth of an inch. The female beetles average somewhat larger than the males.

DISTRIBUTION AND DISSEMINATION.

Commerce has served to distribute the tobacco beetle widely, and probably this insect occurs now in all countries having a temperate, subtropical, or tropical climate. In warm tobacco-growing countries such as Cuba and the Philippines, where the bettles are numerous and breed continuously throughout the year, they are being sent out constantly to other countries in shipments of cigars or in leaf tobacco. The nature of their food and their habit of living and breeding continuously in their food substance aid in their spread without much effort on their part.

The increase and spread of the insect in tobacco factories in this country within comparatively recent years has been very noticeable. Experienced tobacco dealers and manufacturers attribute this to the more general use of steam for heating factories and other buildings. The higher and more uniform temperatures maintained make breeding conditions more favorable for the insect, and the chance that development will be checked or the insects killed out by the cold weather is not as great as before steam heat was employed.

The recent rapid expansion of the tobacco industry has carried the pest, in leaf tobacco or in tobacco products, to many localities where until within the last few years it had been unknown.

In this country the beetle now is disseminated so generally that it is a common occurrence to find it in show cases and storage rooms or humidors in cigar stores where worthless or infested stock is not properly treated or destroyed. The majority of shipments returned to cigar and tobacco factories come from dealers in the South and from other localities where climatic conditions are especially favorable for the rapid increase of the insect. Even in summer comparatively few complaints come from dealers in certain of the Northern States and Canada. In view of these facts, when damaged goods are returned to the manufacturers after having been in the hands of the dealers for some time, it is always possible that the product was not infested when shipped out from the factory.

FOOD SUBSTANCES.

The tobacco beetle feeds upon a variety of dried vegetable substances and upon a few of animal origin. Its more common food is cured leaf and manufactured tobacco. In drug stores and grocery stores often it is found infesting dried roots and leaves of certain kinds and pressed yeast cake. In drug stores frequently it becomes a serious pest and causes considerable loss. Numerous cases of injury to plush upholstering in furniture and to dried plants in botanical collections have been recorded. The insect also feeds upon tobacco seed.

LIFE HISTORY AND HABITS.

THE EGGS.

Period of incubation.—The egg stage at ordinary temperatures in summer lasts from 6 to 10 days. In warm weather during summer it averages about 8 days. Eggs kept at a constant temperature of

80° F. nearly all hatch the sixth or seventh day after they are laid. Cool weather may retard hatching for a considerable time.

THE LARVÆ.

Newly hatched larvæ are somewhat more active than later, and owing to their extremely small size readily enter boxes or containers holding tobacco. When exposed to light, the larvæ disappear within the food substance or under cover as quickly as possible. They are able to crawl for short distances and often migrate from infested to uninfested material. This habit sometimes accounts for the quick appearance of injury in freshly made cigars. Partly grown larvæ shaken from leaf tobacco have been found on cigar makers' tables. These larvæ easily enter the open ends of the cigars, and in a very short time their work may be noticed in the bundle or box of finished cigars. Several cigars in a box or package may be injured by a single larva. Preference is shown for the thinner or chaffy leaves of cured tobacco, and for certain types of high grade that are mild and sweet flavored. (See fig. 3.) Strong, heavy types of leaf tobacco ordinarily are not injured to such an extent as are the milder or thinner types, unless stored for a long time. Leaf tobacco which is fire cured or smoke cured, such as that grown in the dark-tobacco sections of Virginia and in the "black patch" of Kentucky and Tennessee, seldom is badly injured. This is due in part, perhaps, to the flavor or quality given the leaf by the smoke, as well as to the natural qualities of tobacco of this type. The smoke seems to act for a time as a repellent, since the same type of leaf, flue cured, is attacked readily, although not to so great an extent as lighter bodied types. These types, as well as all others, however, are more likely to be injured after the leaf has become aged. The changes brought about by long storage of any tobacco seem in some way to make it more acceptable as food for the larvæ.

Length of larva stage.—At ordinary room temperatures in summer the larva or feeding stage extends over a period of from 30 to 70 days, depending mainly on the temperature and on the character, abundance, and condition of the food. In cold weather the larvæ become dormant and may remain in this condition for some time. It is mainly in this stage, in cool climates, that the insect passes the winter. When the larvæ have finished feeding and are incased within the pupal cells they are able, either as larvæ or as pupæ, to stand a considerable degree of cold. Larvæ within the cells are also more able to resist treatment with fumigants. Activity in the larva stage ceases at temperatures ranging from 60° to 67° F. The most favorable conditions for rapid development of larvæ are a suitable food substance in a compact or concentrated form, high and uniform temperature, high humidity, and protection from strong light and from rapid evaporation.

The pupal cells.—After the larvæ have become fully grown and ready to transform to the pupa stage they construct cells or cocoons, usually within the food substance. In leaf tobacco these cells usually are found along the midrib or in folds of the leaf. In boxes of cigars some of the cells may be found between the cigars and the sides of the box, but the greater number are found within the cigar. In leaf tobacco the cells frequently are incomplete, the larvæ using folds of the leaf for part of the cells. Within dense substances the surrounding material forms the necessary protection, the walls of the cell being fragile and thinly lined. The cells are more or less egg-shaped and about one-fifth of an inch long. Often they are without definite shape.

The prepupa stage.—Before transformation to pupæ there is ordinarily a period of from 4 to 12 days during which the larvæ within the cells undergo structural changes, but if exposed to low temperatures they may remain in the cells for a considerable time before these changes take place. Before changing to pupæ the larvæ lie in a curved position within their cells, and their movements cause the cells to become considerably larger than the larvæ. Their bodies then contract and become more deeply wrinkled.

THE PUPÆ.

The pupa stage of the tobacco beetle at room temperatures during the warmer months of the year lasts from 5 to 10 days. The average of 38 records obtained at Tampa, Fla., during July, 1913, was found to be 7.8 days.

THE ADULTS.

When the change to the beetle or adult stage has taken place the beetles remain inactive in the cells for from 3 to 7 days. After emerging they remain at rest for a day or more, their color gradually deepening to reddish brown. At first the beetles are comparatively soft, and they do not attain their final degree of hardness until they are ready to move away from the pupal cell. They crawl or fly about actively and are capable of flying for a considerable distance. They avoid intense light and move about most actively in subdued light or in darkness. When in the dark they are attracted toward subdued daylight or to artificial light. In tobacco warehouses they may often be found in large numbers at the windows in late afternoon, the flight toward the windows being heaviest at sunset. During the day the beetles will be found most numerous in secluded places, such as crevices in the walls or in the leaf tobacco. They have a habit of feigning death when disturbed. The adults generally begin to mate the second or third day after becoming fully mature. In tobacco warehouses the beetles seldom are found active at temperatures below 65° F. Activity increases as the temperature becomes higher, but ceases between 117° and 120° F.

Length of the adult stage.—In warm rooms, or in summer, the beetles die much sooner than when emergence occurs during cooler weather. Although they may gnaw through tobacco or other food substances to escape from the locality where transformation took place, little evidence of feeding has been observed. Adults have been found to lay eggs and live the normal length of time whether food was present or not. Under usual conditions they live from three to six weeks.

Oviposition.—Egg laying usually begins in from two to six days after emergence. In warm places where tobacco is not subjected to temperatures much below 70° F., eggs may be found at any time. In the Middle and Northern States, where tobacco is kept in unheated buildings and the temperature is about the same as out of doors, the eggs are laid only during the warmer months of the year. In experiments at Richmond, Va., the last eggs were obtained from beetles kept in an unheated building on October 28, 1914, and the first eggs were obtained the following spring on May 2. There seems to be a rather common belief that the eggs are laid on the leaf of tobacco in the fields or during the process of curing, and that these eggs do not develop until the tobacco is handled or made up into cigars or other products. This is not the case, as the eggs at ordinary temperatures hatch a few days after they are laid, and the beetle does not infest tobacco until after it is cured. The eggs adhere very lightly to leaf tobacco and are dislodged easily by handling. The beetles deposit their eggs in crevices or folds of the leaf, or in secluded places away from the light, and where the closely packed food substance protects the eggs from evaporation. The egg-laying period normally lasts from 2 to 17 days, and the number laid by each female is approximately 25 to 30.

SUMMARY OF LIFE HISTORY.

The insect lives in its food substance during all stages of its existence. In tobacco or other food substance kept constantly warm breeding is continuous, and there may be as many as five or six generations a year. Under usual conditions in tobacco warehouses in the latitude of Virginia and Tennessee there are three or four generations a year. The time required to complete the life cycle of the insect depends mainly upon temperature and may be as short as 45 days, normally varying in summer from 45 to 70 days. Eggs are laid in the food substance. They hatch in from 6 to 10 days. The larva period is from 30 to 50 days and the pupa period from 6 to 10 days. Under usual conditions adults live from three to six weeks. In temperate climates the insect passes the winter mainly in the larva stage. It thrives best where the temperature and humidity are high and in tobacco or other food substances protected from rapid evaporation.

SEASONAL ABUNDANCE AND NUMBER OF GENERATIONS.

In food substances kept constantly warm all stages of the beetle may be found at any time, and the great variation in the time required for development gives constant overlapping of generations. Under usual conditions in tobacco warehouses and in unheated buildings there are, however, well-marked periods when the adults are most abundant. In the latitude of Virginia and Tennessee there seems to be a period of greater abundance of the adults coinciding with the first warm weather in June, and again in August and early September. At Clarksville, Tenn., starting with the egg stage, in early May, three or, under some conditions, four generations are possible. At Richmond, Va., three generations may occur under warehouse conditions before the appearance of cold weather, the adults appearing in May, July, and October, and from the adults emerging earliest in the spring there may possibly be a fourth generation reaching the adult stage before winter.

NATURAL CHECKS.

Several natural agencies serve to check the increase and spread of the tobacco beetle, among which are low temperature, the drying out of food, the molding of food, parasitic and predatory insects, mites, jointed spiders, and false scorpions.

CLIMATIC CONTROL.

In the temperate zone a comparatively small proportion of the insects survive the winter when exposed to even moderate cold, long continued, or to sudden abnormal changes in temperature. Severe freezing at temperatures lower than 10 degrees above zero (Fahrenheit), even for a short time, exterminates them completely. Evidences of the effect of freezing on the tobacco beetle have been ob-

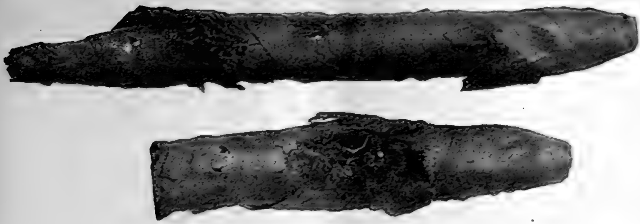

FIG. 5.—Cigars showing work of a solpugid, or jointed spider. The holes were torn by the solpugid in order to reach larvæ and pupæ of the tobacco beetle within the cigars.

served on many occasions, and it is not uncommon to find leaf tobacco or other food substances, which have been exposed to low temperatures, completely free from all live stages of the tobacco beetle, although its condition shows that there had been a heavy infestation previously.

DRYING OUT AND MOLDING OF FOOD SUBSTANCES.

The multiplication of the beetles is checked severely when the food substance is exposed to excessive evaporation, and when it becomes moldy, as it does frequently, more or less complete extermination of the beetles results. It is often owing to this fact that infestation from damaged or worthless products which have become moldy does not extend to uninfested products near by.

PARASITIC AND PREDACIOUS ENEMIES OF THE TOBACCO BEETLE.

INSECTS.

Among enemies that prey upon the tobacco beetle the most important, so far as known, is a reddish-brown beetle[1] about one-fourth of an inch in length. Both the adult and its larva, a pink worm slightly larger than the adult, feed ravenously on different stages of the tobacco beetle.

Several species of four-winged, wasplike parasites[2] of the tobacco beetle are found in infested warehouses and manufactured tobacco. Some of these are extremely abundant and doubtless are important factors in natural control.

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[1] *Thaneroclerus girodi* Chevrolat; order Coleoptera, family Cleridae.

[2] *Aplestomorpha pratti* Crawford, *A. vandinei* Tucker, and other species.

OTHER ENEMIES.

A small mite[1] feeds on the eggs of the tobacco beetle, and at Key West, Fla., a large jointed spider[2] (see fig. 5) and a much smaller scorpion-like spider[3] were found to feed on the larvæ. The jointed spiders frequently tear large holes in cigars in search of their prey.

REPRESSION.

PREVENTIVE MEASURES.

In cigar stores and small establishments it is not difficult to eradicate the tobacco beetle. Infested stock may be treated and the building thoroughly cleaned. The humidors or storage closets should be perfectly tight, and infested stock should be destroyed or treated as soon as signs of infestation are noticed.

In large factories and tobacco warehouses, however, complete eradication in many instances is extremely difficult, or perhaps impossible. The factories in some cases are old wooden buildings, roughly built and containing innumerable cracks and crevices in which tobacco dust and refuse have accumulated, offering ideal hiding and breeding places for the beetles. Even in modern factories of brick or concrete construction it is difficult to eradicate the insect completely after it has once become established, but it is much easier, of course, to keep such buildings clean and free from accumulations of refuse material in which the beetles may breed. The measures to be employed in eradication work or in sterilizing buildings will depend upon local conditions.

For destroying the different stages of the beetle in crevices of floors or walls, live steam applied through a nozzle from movable pipes or hose, hot water, gasoline, carbon disulphid, or dilute ammonia may be used. Suction cleaners also may be used to advantage for such work. (See fig. 6.) In cigar factories the stock of leaf tobacco should be kept in a tight or screened room, as far as possible from the rooms in which the cigars are made or handled. Trays of unsorted cigars should be covered or kept overnight in a screened compartment, as eggs deposited on the cigars at this time, even from a single beetle, may be the cause of heavy losses afterwards.

SOURCES OF INFESTATION IN FACTORIES.

In cigar and tobacco factories the greater number of beetles are brought in with the leaf tobacco. Beetles also breed from infested stock and from accumulations of refuse material. Factories in some

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[1] *Cheyletus* sp.; class Arachnida, order Acarina.
[2] Class Arachnida, order Solpugida.
[3] Class Arachnida, order Pseudoscorpiones.

instances are in close proximity to tobacco warehouses where beetles are present in large numbers. A comparatively small number of beetles in rooms in which cigars are made, or in rooms where the cigars or other classes of manufactured tobacco are packed, is sufficient to infest the stock seriously by depositing eggs in it. The protection of the finished product before it is packed is generally of more importance than the condition of the raw material, as with most classes of manufactured tobacco the process of manufacture frees it from different stages of the beetle present in the raw material.

COLD STORAGE.

The modern cold-storage plants now found in most cities furnish a convenient, inexpensive, and effective means of sterilizing infested tobacco. The method has been used to a considerable extent, but the temperatures more commonly used have the effect of suspending insect activity instead of causing death. Cold storage at temperatures between 32° and 65° F. prevents further damage as long as the material is held in storage. The different stages of the beetle are not killed, however, and activity is resumed when the tobacco is removed from storage. When lower temperatures are available a more satisfactory and effective method is to subject the tobacco for a week or more to the lowest temperature that can be obtained. A long series of experiments with infested tobacco in cold storage at low temperatures has shown this method to be thoroughly effective.

The cold-storage room should be as dry as possible, and the cigars or manufactured tobacco should be removed from storage when the air outside is dry, to prevent sweating. Some system of dry cold storage

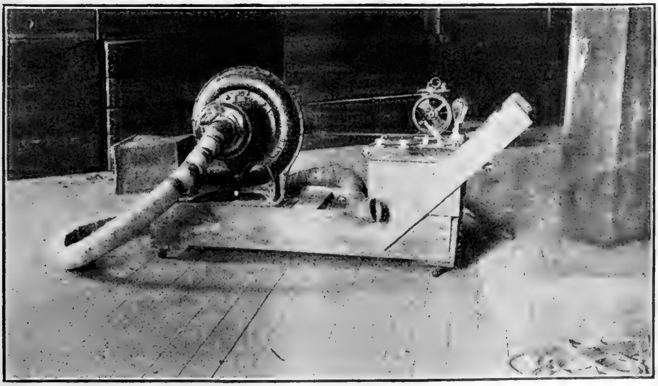

Fig. 6.—Suction fan used for collecting adults of the tobacco beetle in a tobacco warehouse.

or air-tight receptacles for holding the cigars or tobacco is desirable, although not absolutely necessary if care is taken to remove the material when the air is dry. If the material is removed from storage when the air is damp, the condensation of moisture may make the tobacco or cigars more liable to mold, or may cause discoloring, staining, or warping of the boxes or containers.

A large number of cigars placed in cold storage by a manufacturer were kept under observation by the writer. The cigars were not put in containers, the boxes being merely piled on the floor of the cold-storage room. The boxes were removed when the air outside was dry and put under presses in a dry room for a time to prevent warping of the covers of the boxes. The treatment proved thoroughly effective in killing all stages of the beetles. The manufacturer reported that no injury to the cigars as a result of the treatment was apparent. Different lots were kept at a temperature of about 12° F. for from one to four weeks.

Although there are certain objections to the cold-storage method of control, such as loosening of the wrappers of fine cigars by sudden changes in temperature, danger of sweating when removed from cold storage, injury to quality from too rapid aging, etc., it has certain advantages and in some cases may be found more desirable than other methods of treatment. When precautions are taken to prevent sweating, it is evident that the exposure of manufactured or leaf tobacco to cold in a cold-storage room is not more apt to cause injury than the exposure of the same material to low temperatures during winter.

FREEZING DURING WINTER.

In localities where severe freezing occurs the doors and windows of warehouses or other buildings where tobacco is stored may be thrown open at favorable times during the winter and the tobacco subjected to freezing temperatures. This control measure has been employed by tobacco men in different sections of the country, and excellent results have been reported, the degree of success in exterminating the beetles or checking their increase depending upon the temperatures obtained. Experiments made with infested manufactured tobacco have shown that it may be sterilized easily by this means.

The modern practice of storing certain classes of leaf tobacco in hogsheads in sheds, giving practically out-of-door conditions and variations of temperature, furnishes an effective means, in cool climates, of reducing injury to leaf tobacco which may be stored in this manner.

ALTERNATIONS OF HEAT AND COLD.

Experiments made with infested tobacco indicate that the effectiveness of cold in killing different stages of the beetle can be increased by alternations of heat and cold. Sudden and extreme changes in temperature seem more destructive to the beetles than longer exposures to moderate cold. This method is applicable also to cold-storage treatment of infested tobacco.

EFFECT OF HEAT ON DIFFERENT STAGES OF THE TOBACCO BEETLE.

It has been found that adults of the tobacco beetle become inactive after a few minutes' exposure to heat above 117° F., but recover unless, for a considerable length of time, the temperature is kept higher than 120°. An exposure of one hour at temperatures between 140° and 150° proved effective in killing all stages of the beetle. The time required for treatment depends upon the quantity and character of the material. A temperature of from 125° to 140° F., continued for a few hours, or of 150° for a short time, has been found effective under ordinary conditions.

EFFECT OF HEAT DURING THE PROCESS OF MANUFACTURE.

Tests made in tobacco factories have shown that the temperatures reached during certain processes of manufacture are sufficiently high to sterilize the tobacco quickly and effectively as it passes through the driers.[1] Reinfestation of the finished product depends on the methods of packing, handling, and storing.

THE USE OF STEAM IN STERILIZING TOBACCO.

While steam furnishes, under some circumstances, an effective and convenient means of sterilizing empty storage rooms or warehouses, numerous difficulties prevent its use in sterilizing infested tobacco. If leaf tobacco is exposed to steam at high temperatures for any length of time it becomes more brittle, the texture of the leaf and the aroma are changed as the natural oils are drawn out, and the color becomes darker. Notwithstanding the general prejudice against steaming, however, there seems to be considerable evidence that mild steaming may be employed to advantage in treating certain classes of cigar tobacco, and the process is said to have been used to a considerable extent. A convenient method of steaming cigar tobacco in revolving drums, with the steam under pressure of about four atmospheres, is said to have been used successfully in the Philippines.[2] In

[1] Several tests showed that a temperature of about 180° F. was reached.

[2] The Philippine Journal of Science, v. 8, no. 1, 1913.

the application of steam the principal requisite is to see that the tobacco does not become too wet. The temperature should not be too high or the steaming be long continued.

TRAPPING.

In rooms where cigars or manufactured tobaccos are packed a very few beetles are capable of doing a great deal of damage by depositing eggs on the finished product. In many cases the process of manufacture has sterilized the tobacco thoroughly, and precautions to keep the beetles away during the time it is handled and packed will prevent damage to the product later. The windows of packing rooms should be examined daily and the adults destroyed by brushing them onto sticky fly paper, or by other means. The adults are readily attracted to hands of leaf tobacco suspended in the rooms and may be collected in this way. The leaf tobacco used for this purpose should be heated or fumigated once each week in order to destroy the eggs before they have time to hatch. The adults are attracted toward the light, and an effective means of trapping consists of inclosing electric lights in sticky fly paper. (See fig. 7.) Sheets of fly paper spread on the window sills also were found to destroy many beetles. The adults fly more readily to blue or violet light than to red or orange. Color screens, however, cut down the intensity of a light. Ordinary electric-light bulbs of clear glass, of the improved and nitrogen-filled types, which transmit light rich in rays of short wave lengths, are well adapted for use as sources of light in connection with trapping.

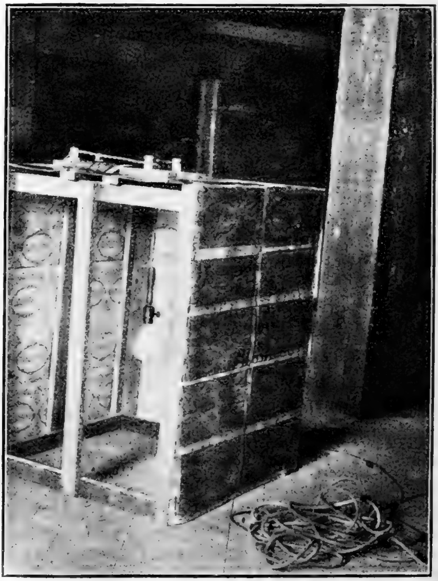

FIG. 7.—Arrangement for using sticky fly paper to collect adults of the tobacco beetle in tobacco warehouses.

FUMIGATION.

Fumigation has been in general use for many years as a method of destroying certain classes of insects and is a standard weapon against insects infesting mills and warehouses. It may be used to advantage in controlling the tobacco beetle, although this pest has been found to be considerably more resistant to fumigants than most insects. The insulation afforded by the pupal cells and by compressed tobacco seems to protect the larvæ or pupæ within from the action of the fumigant. A few insects protected in this manner are likely to survive, although all stages not specially protected are killed. In most cases, however, only a small percentage of the insects survive, and these, if an additional treatment is thought advisable, may be destroyed by a second fumigation given about two or three weeks later. Adults and eggs are the only stages likely to be present at this time, and these unprotected stages are easily destroyed by the fumigant. In the treatment of infested tobacco it has been determined by many experiments that stronger dosages of fumigants must be used than are employed ordinarily against other insects.

Expert tobacco men have examined and kept under observation tobacco and cigars fumigated with carbon disulphid and hydrocyanic-acid gas, and all were of the opinion that these fumigants had no noticeable effect upon the tobacco. In order that it might be determined whether or not any deposition of cyanogen in cigars occurs as a result of the hydrocyanic-acid gas treatment, different lots of freshly made cigars were fumigated with heavy dosages and sent to the Bureau of Chemistry, United States Department of Agriculture, for examination. No trace of hydrocyanic-acid was found in any of the samples. Duplicates from each lot were also submitted to expert cigar men, and all reported no apparent difference between the fumigated and unfumigated cigars.

The properties and characteristics of the various chemicals used in fumigation should be understood thoroughly in every particular by the operator in order that necessary precautions may be taken and the work done properly. The process of fumigation, however, is simple and easily applied.

HYDROCYANIC-ACID GAS.

For the generation of hydrocyanic-acid gas in fumigation, sodium cyanid ($NaCN$) or potassium cyanid (KCN), sulphuric acid (H_2SO_4), and water are necessary. The hydrocyanic-acid gas,[1] which is the killing agent, is produced by the action of the sulphuric acid (diluted with water) on the sodium or potassium cyanid. A high grade of the cyanid should be used, as the presence of adulterants reduces greatly the amount of hydrocyanic-acid gas given

[1] Hydrocyanic-acid gas is colorless and one of the most deadly poisonous gases known.

off. Sodium cyanid at present is used for fumigation more generally than is potassium cyanid and is more readily obtained.

Dosages to use.—Sodium cyanid should be combined with acid and water to generate the hydrocyanic-acid gas, according to the following formula:

Sodium cyanid (grade guaranteed to contain not less than 51 per cent of cyanogen and practically free from chlorin)	avoirdupois ounce	1
Sulphuric acid (commercial [1])	fluid ounces	1½
Water	do	3

Should potassium cyanid be used in place of sodium cyanid,[2] the cyanid should be combined with sulphuric acid and water according to the following formula:

Potassium cyanid (98 to 99 per cent grade and guaranteed to contain not less than 38.4 per cent cyanogen)	avoirdupois ounce	1
Sulphuric acid (commercial [1])	fluid ounce	1
Water	fluid ounces	3

The amount of chemicals given in either of these formulas is sufficient for the fumigation of 100 cubic feet of space in the fumigation closet or room. The exposure to fumigation should last at least 24 hours. Best results are obtained by fumigating at temperatures above 70° F. For general use 4 ounces of cyanid, either of sodium or potassium, to 100 cubic feet will be found fairly satisfactory. This dosage when sodium cyanid [3] is used requires 4 ounces of cyanid, 6 fluid ounces of sulphuric acid, and 12 fluid ounces of water. The cyanid is weighed, and the liquids, sulphuric acid, and water are measured.

For generators use earthenware jars, and these should be deep enough to prevent the liquid from boiling over. Since the gas generated is lighter than air, *place the generator underneath the material to be fumigated or on the floor of the room.* Place the chemicals for fumigating in the generating jar in the following order: *First, water; then sulphuric acid; last, just before closing the fumigating closet or room, the cyanid. Do not pour water on to the acid. Avoid breathing the gas, as it is deadly poisonous. The reaction of the chemicals*

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[1] Commercial sulphuric acid (about 1.84 sp. gr. or 66° Baumé) which is approximately 93 per cent pure is commonly used for fumigation.

[2] The yield of hydrocyanic-acid gas from 1 ounce of high-grade sodium cyanid is equivalent to the yield from approximately 1⅓ ounces of high-grade potassium cyanid.

[3] Sodium cyanid is now on the market in molds or "eggs" weighing 1 ounce each. It is advisable to use this form, since it is easily handled and the necessity for weighing is obviated. *The poison should be kept in tight cans, properly labeled, and extreme care should be taken in handling it. Sodium cyanid and potassium cyanid are among the most poisonous substances known.*

when mixed is extremely rapid, and the generation of the deadly gas begins at once.[1]

The fumigation closet should be perfectly tight to prevent escape of gas. In fumigating storage rooms or buildings, arrange so that the windows or doors can be opened from the outside. *Do not enter the room until it is thoroughly aired.* When the chemicals are handled with care and all details of the method understood, there is no special danger to the operator, and the method has been used in insect control for many years with few records of serious accidents. It should be stated, however, that hydrocyanic-acid gas is fatal to human beings if breathed in any quantity.[2]

CARBON DISULPHID.

While carbon disulphid is not as effective as hydrocyanic-acid gas, the ease with which it may be used makes it for some purposes the more desirable fumigant, particularly when the space to be fumigated is small or when only a small quantity of material is to be treated. The liquid carbon disulphid (CS_2) merely has to be poured into a shallow dish placed *at the top* of the compartment to be fumigated and allowed to evaporate. The gas is heavier than air and settles downward. This methods of treatment is a favorite one with many cigar dealers, the main objection being the danger of fire.[3] Carbon disulphid should be used at a rate of not less than 4 pounds of the liquid to 1,000 cubic feet of space. When only a small space is to be fumigated and the cost of the treatment is consequently slight, the exact amount of the carbon disulphid is of no particular importance, providing the amount is in excess of the dosage recommended. Best results are secured at temperatures above 70° F. The time of exposure should be from 24 to 48 hours. All odor of the fumigant disappears quickly when the substance treated is exposed to the air. Tobacco or cigars, when properly aired, do not retain even the slightest trace of the gas, and quality and flavor are not changed perceptibly.

DESTRUCTION OF TOBACCO BEETLE BY MEANS OF ROENTGEN RAYS.

A process of destroying the tobacco beetle in cigars at the factories by the use of Roentgen rays has been exploited commercially and the method of treatment and apparatus used for the purpose at the pres-

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[1] Care must be taken in fumigating buildings in close proximity to dwellings, as the liberation of a large volume of hydrocyanic-acid gas may endanger the persons within the dwellings.

[2] In case of accidental inhalation of the gas, the person affected should be kept in the open air and be required to walk to increase respiration.

[3] Carbon disulphid vapor is highly inflammable and explosive when mixed with air in certain proportions, but it is not more dangerous to handle than gasoline. The fumes should not be breathed, as the gas is poisonous.

ent time give apparently satisfactory results. By this method the cigars in sealed boxes, ready for shipment, are subjected to Roentgen-ray radiation of great power and intensity. Recent improvements in apparatus have made possible exposures which could not be obtained readily or were not practicable in commercial work with earlier forms of apparatus.[1]

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[1] A detailed report of experiments made by the writer with X rays has been published in the Journal of Agricultural Research, Vol. VI, No. 11. "Effect of Roentgen rays on the tobacco or cigarette beetle and the results of experiments with a new form of Roentgen tube." Washington, Government Printing Office, 1916.

PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO INSECTS INJURIOUS TO TOBACCO.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Tobacco Budworm and its Control. (Farmers' Bulletin 819.)

Tobacco Hornworm Insecticide: Recommendations for Use of Powdered Arsenate of Lead in Dark-tobacco District. (Farmers' Bulletin 867.)

Tobacco Splitworm. (Department Bulletin 59.)

Methods of Controlling Tobacco Insects. (Entomology Circular 123.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

So-called Tobacco Wireworm in Virginia. (Department Bulletin 78.) 1914. Price, 5 cents.

Tobacco Thrips and Remedies to Prevent "White Veins" in Wrapper Tobacco. (Entomology Circular 68.) 1906. Price, 5 cents.

Tobacco Thrips, a New and Destructive Enemy of Shade-grown Tobacco. (Entomology Bulletin 65.) 1907. Price, 5 cents.

Principal Insects Affecting Tobacco Plant. (Farmers' Bulletin 120.) 1900. Price, 5 cents.

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THE BOLL-WEEVIL PROBLEM

WITH SPECIAL REFERENCE TO MEANS OF REDUCING DAMAGE

W. D. HUNTER

In Charge of Southern Field Crop Insect Investigations

Cotton field in weevil territory producing profitable crop through proper methods

FARMERS' BULLETIN 848

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C. August, 1917

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1917

THIS BULLETIN contains a general account of the boll-weevil problem. It deals with the history of the insect in the United States, the damage it has done in different regions, and the reasons for local variations in damage, the indications for the future, the habits of the weevil in so far as they are connected with control measures, and the means of reducing the injury it causes by methods which have been tested in many experimental fields and by large numbers of practical planters.

THE BOLL-WEEVIL PROBLEM, WITH SPECIAL REFERENCE TO MEANS OF REDUCING DAMAGE.

CONTENTS.

THIS bulletin, dealing with work done under the direction of Dr. L. O. Howard, Chief of the Bureau of Entomology, is intended to cover in a general way the whole field of control of the boll weevil, and as this control is inseparably connected with the life history and habits of the insect and, in fact, must be based thereon, attention is given to the principal features of the insect's economy. In addition, information is given relating to the amount of damage done, the extent of infested territory, and such other matters as are of special interest at this time.

Like many of the most important injurious insects in this country, the cotton boll weevil is not a native of the United States. Its original home was undoubtedly in the plateau region of Mexico or Central America, and originally it may have fed upon some plant other than cotton. This is not necessarily the case, however, since there is evidence that the same region is the original home of the cotton plant itself. Previous to 1892 the insect had spread through much of Mexico, but little is known regarding the extent or rapidity of this dispersion. The records indicate, however, that it probably had caused the abandonment of cotton in certain regions. About 1892 the boll weevil crossed the Rio Grande near Brownsville, Tex. It may have flown across, or it is possible that it was carried over in seed cotton to be ginned at Brownsville. By 1894 it had spread to half a dozen counties in southern Texas and was brought to the atten-

NOTE.—This bulletin is a revision of Farmers' Bulletin 512.

tion of the Bureau of Entomology. A preliminary examination, made under the direction of Dr. L. O. Howard by Mr. C. H. T. Townsend, showed the enormous capacity for damage of the pest. Subsequent events have verified in every way the predictions that were made at that time, when the insect had not attracted any considerable amount of attention in the South. Since 1894 the boll weevil has extended its range annually from 40 to 160 miles, although in several instances the winter conditions have been such as to cause a decrease in the infested area. During the first 10 years after its advent into this country the annual rate of spread was 5,640 square miles. From 1901 to 1911 the annual increase in the infested territory averaged 26,880 square miles. In 1916 it reached 71,800 square miles. Of course, the figures given do not refer to the area in cotton. In many parts of the infested territory the area devoted to cotton is much less than 10 per cent of the total area.

The territory in the United States in which the boll weevil was found to occur at the end of the year 1916 is shown in figure 1.

Outside of the United States the boll weevil is known throughout the larger portion of Mexico and southward to Guatemala and Costa Rica. It is known to occur also in the eastern half of Cuba.

A form of the boll weevil with different habits is found in the mountains of Arizona. It feeds upon a wild plant related to cotton. It has not been found to attack any of the planted fields in Arizona, but experiments have shown that it readily attacks the cotton plant.

DAMAGE.

The damage done by the boll weevil varies greatly from year to year and also in different parts of the infested area. As the rainfall increases the damage becomes greater. In prairie regions, where the insect obtains little protection through the winter, it never becomes so numerous as in other quarters where favorable conditions for hibernation are found. These facts, together with variations due to winter conditions, make it rather difficult to estimate the exact damage that has been done. Some years ago the writer stated, from the statistics then available, that the weevil caused a reduction of at least 50 per cent of the cotton crop in regions invaded by it, but that after the first few years the farmers generally resorted to proper means greatly to reduce this loss. Such an initial falling off in production was confirmed by Prof. E. D. Sanderson, formerly State entomologist of Texas, who arrived at his figures in an entirely different way. In many individual cases the means of control recommended by the Bureau of Entomology and demonstrated by the States Relations Service have been applied so successfully that the crop has been fully as large as before the coming of the weevil.

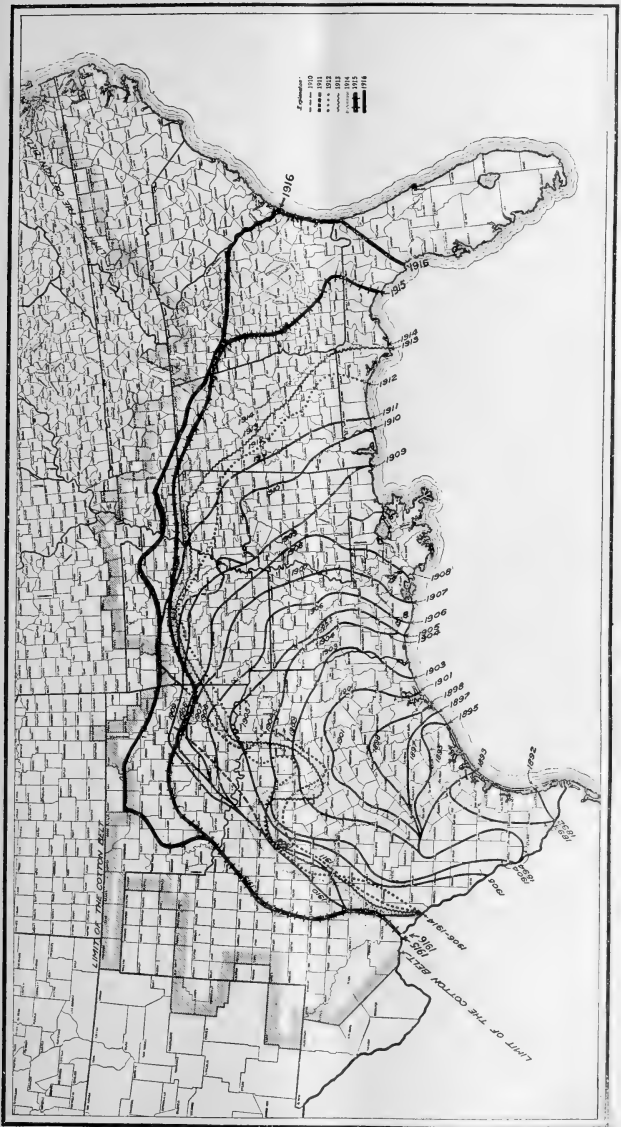

FIG. 1.—Map showing spread of the Mexican cotton boll weevil in the United States from 1892 to 1916.

The average yield per acre in Texas from 1893 to 1901 (when the weevil had not done damage sufficient to affect the general production) was 0.40 bale. The average since that time, 1902 to 1915, was 0.35 bale. By comparing these periods we have a reasonably accurate basis for estimating the damage the insect has done. The difference is 0.05 bale, or 25 pounds of lint per acre each year. At prices current through the period this means an annual loss, without considering the value of the seed, of at least $2.70 per acre which has been sustained by the cotton planters of Texas. Assuming that the area planted in cotton in Texas has averaged 10,000,000 acres, the annual loss for the State for the period from 1902 to 1915 has been $27,000,000.

Another indication of the manner in which the weevil has affected cotton production is revealed by a comparison of statistics from Louisiana and Texas. From 1899 to 1904 the acreage in Texas and Louisiana increased at about the same proportion, but the crop in Texas decreased at the same time that the crop of Louisiana was increasing. There is an exception to this statement in the years 1900 and 1904, in which the production in Texas did not decrease, but these years were exceptionally unfavorable for the weevil and at the same time very favorable for the general growth of the cotton. In 1907 the yield per acre in Texas (0.24 bale) was the smallest in history. This followed a winter so mild that more than the usual number of weevils overwintered.

Before the general invasion of the Texas cotton fields by the boll weevil, the average yield of lint per acre in that State was 187 pounds. A steady decrease in production per acre took place until 1908, at which time the production had become reduced to 175 pounds of lint per acre. In 1909 a tendency to increased production per acre began to develop. Up to 1915, however, this had not reached the average before the invasion of the weevil.

In Louisiana the production per acre before the invasion of the boll weevil was 262 pounds. Beginning with 1903 a sharp reduction began and continued until 1909, at which time the production per acre was 181 pounds. The yield per acre in this State has continued to decrease since 1909, but the falling off is not nearly as marked as for the period from 1903 to 1908.

In connection with the reduction in yield in Texas and Louisiana, it is very interesting to note a constant tendency toward increased production per acre in the eastern States. For instance, North Carolina averaged 225 pounds of lint per acre from 1895 to 1907. At that time a sharp increase in production began, reaching 285 pounds per acre in 1913. It is thus evident that the effect of the boll weevil on the production of cotton in the United States has been masked by reason of the fact that the yield per acre in the eastern cotton

States has been increasing to such an extent as to offset very largely the reduction caused by the insect elsewhere.

Undoubtedly for several years the boll weevil has caused a loss of about 400,000 bales of cotton annually. Although farmers in older regions, in many cases, are increasing their production, there is loss in the newly infested regions which offsets that gain. A conservative estimate shows that since the weevil has invaded this country it has caused a loss of 4,550,000 bales of cotton, with a value of about $250,000,000.

The figures which have been cited show clearly the enormous reduction in cotton production which the boll weevil causes. In order to make the picture complete, however, it is necessary to call attention to the effect the weevil has on the production of crops other than cotton. Wherever the insect invades a region, diversification of crops and animal husbandry receive a powerful impetus. This is shown, for instance, in the State of Mississippi. For the years preceding the advent of the boll weevil, namely, 1904–1908, the average value of all crops was $116,783,104. For the boll-weevil years, 1909–1913, the average was $132,031,800. The loss in cotton production was more than offset by the increased planting in corn, forage, and other crops. The State of Louisiana shows a similar experience. The total value of all crops from the years 1899 to 1902, during which time the boll weevil was not present in the State, was $67,394,152. During the first five years after the invasion of the insect the average value was $88,776,272. There was then a drop in values during five years of serious damage from 1908 to 1912, when the average value was $78,111,000. The reaction became complete during 1913 and 1914, when the average value of the Lousiana crops reached $94,884,472.

The criticism might be made that the statistics given in the preceding paragraphs are misleading because they deal with values which fluctuate from year to year, and not with actual volume of production. It is to be said, however, that the periods covered are sufficiently long to strike a probable average. That is to say, the fluctuations in any one 5-year period are likely to be about the same as in other 5-year periods. Moreover, the use of values is helpful on account of the bearing it has on the amount of money in circulation and consequently on the prosperity of the people. In this respect values are more suggestive than the volume of production, for the reason that large yields frequently are accompanied by low prices.

PROSPECTS.

Reference has been made to the greater damage inflicted in moist regions and where the shelter for hibernation is best. The records of the Weather Bureau show that the annual precipitation increases very rapidly from the West to the East in the cotton belt. This is especially the case during the early growing season of cotton, namely, April, May, and June. The precipitation in the greater part of the cotton-producing area in Texas is normally about 40 inches. In Louisiana, Mississippi, and the eastern States of the cotton belt it is more than 50 inches, and sometimes exceeds 60 inches. The records that have been kept in Texas show that the damage has always been greater in wet seasons and that the insect has affected land values most where the general conditions approach those of the eastern part of the cotton belt. Without the assistance that is furnished by climatic conditions, especially dry weather during the spring, the farmers of Texas would not have been by any means so successful in producing cotton during the last few years as they have. The system of control outlined in this bulletin increases greatly in effectiveness when assisted by weather conditions. Fortunately, in Texas this assistance is given under normal conditions. When this assistance is above the normal, as in 1904 and 1906, the crops will be exceedingly large.

On the other hand, it is clear that the problem of the control of the boll weevil will be more difficult as the pest continues its invasion of the cotton belt. It can not be considered, therefore, that the problem is as yet completely solved. Better means of control must be devised for the region that is becoming invaded, and, if possible, means must be devised that will reduce the enormous loss that is suffered, especially during unfavorable seasons, in Texas. The principal work of the Bureau of Entomology at this time is in attempting to devise means for this requisite additional control.

Though the eastern planter must expect a more serious problem than that which confronted the farmers of Texas, the means of control outlined in this bulletin will enable him to continue production, though probably at a reduced profit. The sooner he adapts his plantation management to the necessary changes the less the loss will be.

Very frequently an error is made in considering that boll-weevil injury is approximately the same in localities in the same latitude. South Carolina planters, for instance, are likely to consider their situation similar to that in central Arkansas, which is in the same latitude. As a matter of fact, the activity of the boll weevil is not governed by latitude but by climatic conditions. The Gulf Stream creates conditions in South Carolina that are similar to those in regions considerably farther south, in the Gulf States. Temperature, rainfall, and the number of days in the growing season are about the same in central South Carolina as in northeastern Louisiana.

WORK UPON WHICH THIS BULLETIN IS BASED.

As has been stated, the danger from the boll weevil was appreciated from the beginning by Dr. L. O. Howard, Chief of the Bureau of Entomology. More or less continuous work on the vulnerable points in its life history and the possibility of control in various ways has been done. At first this was not extensive, although it showed the essential steps necessary in the control of the pest. Later Congress made available large appropriations for the exhaustive investigation of the insect and of means of reducing its damage. Work was begun under the first large appropriation by the establishment of a laboratory at Victoria, Tex., and the beginning of extensive field experiments. It has been the practice from the beginning to carry on field experimental work in direct connection with the laboratory investigations. Later the headquarters of the investigation were moved from Victoria, Tex., to Dallas, Tex., on account of the continued spread of the insect, and then to Tallulah, La. The Bureau of Entomology has conducted experiments during several seasons on a total of more than 20,000 acres of cotton. This experimental work has been located on well-known plantations throughout the infested territory. The special requirements in different regions have been given particular attention.

Aside from the work directly relating to the boll weevil, which has been conducted by the Bureau of Entomology, the Bureau of Plant Industry of this Department has carried on investigations in its province. These have dealt with the breeding of cottons to obtain earliness and productiveness. The farm demonstration service has carried the results of this work directly to the farmers throughout the South.

In addition to the work done by the Department of Agriculture, the States concerned have done their part. Their entomologists have dealt with the boll weevil in connection with the numerous other entomological problems of the States and have contributed valuable results which have been incorporated in this bulletin.

DESCRIPTION AND LIFE HISTORY OF THE BOLL WEEVIL.

The adult boll weevil is about one-fourth of an inch in length, varying from one-eighth to one-third of an inch, with a breadth about one-third of the length. This measurement includes the snout, which is about one-half the length of the body. Variation in size is due to the amount of food the insect has obtained in the larva stage. Individuals from bolls are therefore nearly always larger than those from squares. The color (grayish or brownish) depends upon the time that may have elapsed after transformation to the adult stage. The recently emerged individuals are light yellowish in color, but this passes to a gray or nearly black shade in a few weeks' time. The general appearance of the insect will be evident from the accompanying illustration (fig. 2).

Many insects resemble the boll weevil more or less closely. In fact, there are hundreds of species of weevils in this country that may be easily mistaken for the enemy of cotton. Many erroneous reports about the occurrence of weevils far outside of the infested area have been due to this similarity. The only safe way to determine whether any insect is the boll weevil is to send it to an entomologist for examination. In the field the most conspicuous indication of the presence of the boll weevil is the flaring (fig. 4) and falling of great numbers of squares. Unfavorable climatic conditions and careless cultivation, however, frequently cause great shedding. If excessive shedding be noticed, and the squares upon being cut open show a white, curved grub (fig. 5) that has fed upon the contents, there is little doubt that the boll weevil is the insect causing the damage.

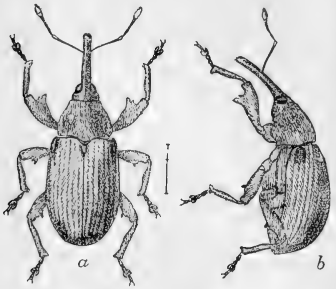

FIG. 2.—Cotton boll weevil: *a*, Beetle, from above; *b*, same, from side. About five times natural size.

The boll weevil passes the winter in the adult stage; that is, as a beetle. In the spring and throughout the fruiting season of cotton the eggs are deposited by the female weevils in cavities formed by eating into the fruit of the plant (see fig. 4). An egg hatches under normal conditions in about three days, and the grub immediately begins to feed. In from 7 to 12 days the larva or grub (fig. 3, at left) passes into its pupa stage (fig. 5, at right), corresponding to the cocoon of butterflies and moths. This stage lasts from three to five days. Then the adult issues, and in about five days begins the production of another generation. Climatic conditions cause considerable variation in the duration of the stages, but on an average it requires from two to three weeks for the weevil to develop from the egg to the adult. Males and females are produced in about equal numbers. The males feed upon the squares and bolls without moving until the food begins to deteriorate. The females refrain from depositing in squares visited by other females. This applies throughout most of the season, but late

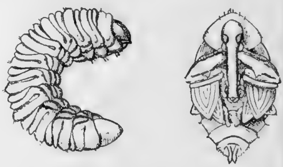

FIG. 3.—Cotton boll weevil: Larva at left, pupa at right. About five times natural size.

in the fall, when all the fruit has become infested, several eggs may be placed in a single square or boll. As many as 15 larvæ have been found in a boll. The squares are greatly preferred as food and as places for depositing eggs. As long as a large supply of squares is present, the bolls are not damaged to any serious extent. The bolls, therefore, have a fair chance to develop as long as squares are being formed.

The cotton boll weevil, so far as known at present, breeds in no plants other than cotton and the wild cotton of Arizona. This has been determined by planting various plants related to cotton in the

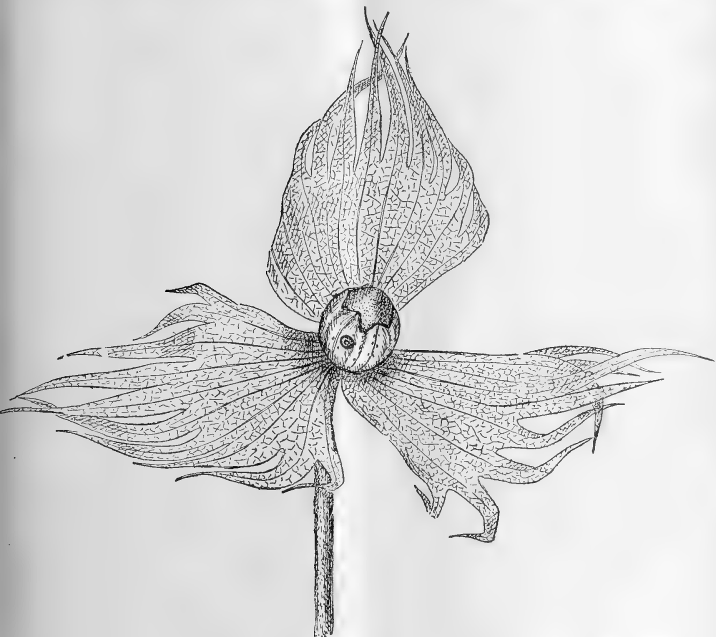

FIG. 4.—Cotton square showing egg puncture of boll weevil and "flaring" of bracts. Natural size.

vicinity of or within infested cotton fields and in cages in which weevils were placed. It has been demonstrated, therefore, beyond any doubt whatever that, at the present time at least, the insect is restricted to the cotton plant as a means of development.

In laboratory experiments performed by B. R. Coad, a weevil developed in the bud of a wild plant related to cotton. Under natural conditions it has not been found developing in that plant, but the experiments may indicate a tendency for the insect to acquire a new food plant. In the adult stage the boll weevil frequently has been found in okra blooms, but repeated observations and experiments have failed to show that it places its eggs in the pods or can develop in them. When confined in bottles, the adult weevil will feed on various substances, such as apples or bananas, but this is only under the stress of starvation.

The chief activity of the boll weevil is from 9 o'clock in the morning to 5 in the afternoon. During this period it has been found in experiments performed in Louisiana that 65 per cent of the eggs are deposited. Eleven per cent of the eggs are deposited early in the morning; that is, from 5 o'clock to 9. There is some activity at night. Six per cent of the eggs were found to have been deposited between 8 at night and 5 o'clock in the morning.

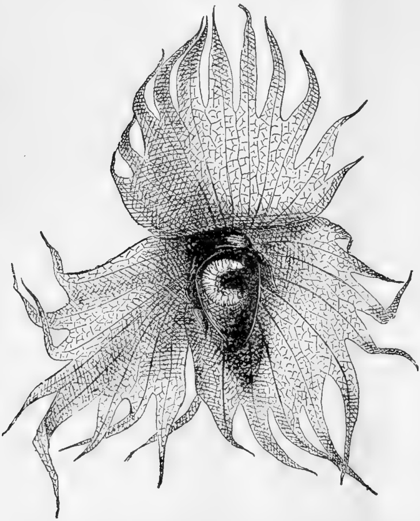

Fig. 5.—Cotton square showing larva of boll weevil in position. Natural size.

Unlike some related insects, the boll weevil is not attracted to light. The fact that somewhat similar species do come to lights in great numbers at times has frequently caused the belief that the pest could be controlled by the use of trap lights.

An interesting habit of the boll weevil is to feign death; that is, to "play possum" or "sull," as it is popularly called. When disturbed, the insects generally contract their limbs and drop to the ground. This habit is not equally strong in all individuals. It has been taken into consideration in plans of control, as will be described beyond.

The age to which weevils live varies under different conditions. During the winter the longevity is much greater than in the summer. During the summer season the majority of weevils do not live longer than 50 days. During the cooler part of the year many of them live as long as six months. The longest lived weevil on record lived from December 10 to the following October, a period of about 11 months. Undoubtedly such prolonged life is exceptional in the cases of the usual form of the weevil. The Arizona weevil, however, has been known to survive for more than a year.

HIBERNATION.

As has been pointed out, the boll weevil passes the winter in the adult stage. In the fall when frosts occur, immature stages may be found in the squares or bolls. Provided the food supply is sufficient, many of these immature stages continue their development at a very slow rate, and adults finally emerge. Thus there may be a somewhat continuous production of adults during the winter. Ordinarily, however, this is not the case, since the frosts that destroy the cotton generally kill practically all of the immature stages of the weevil.

With the advent of cool weather in the fall the adult boll weevils in cotton fields begin to seek protection against the winter. They fly from the fields in every direction, although their movements are governed partially by the prevailing winds. They may fly into hedges, woods, cornfields, haystacks, farm buildings, or other places. Specimens have been found in such situations, and also in considerable numbers in Spanish moss growing some distance above the ground on trees. A number of weevils also obtain hibernating quarters without leaving the cotton fields. These may crawl into cracks in the ground, under grass, weeds, and other trash, and into the burrs from which the cotton has been picked. In some cases several thousand weevils per acre have been found hibernating in such situations. Here, however, the mortality is greater than where the protection is better. In fact, hibernation in the fields is not of great importance except in southern localities. That the majority of weevils that hibernate successfully do not pass the winter in the cotton fields has been shown by many experimental observations and is demonstrated every year in the infested territory by the appearance of the first damage in the immediate vicinity of woods and in other places where conditions for protection are favorable.

During the winter the weevils take no food and remain practically dormant. On especially warm days they may move about to a certain extent. During the very mild winter of 1906–7 hibernating weevils were found moving about more or less throughout the period from November to March.

The number of weevils hibernating successfully has been determined very accurately for different conditions. It varies with the temperature of the winter and with the region. Heavily timbered regions, especially where Spanish moss occurs, show the smallest winter mortality. In Louisiana, out of 25,000 weevils, 2.82 per cent survived the winter of 1905–6. These weevils were placed in a variety of conditions that must have approached those which weevils must encounter naturally. The winter referred to was practically a normal one so far as temperature and precipitation were concerned. In extensive work in Texas during the winter of 1906–7, out of 75,000 weevils 11.5 per cent survived. As in the preceding case, these weevils were placed under diverse conditions in different cages. These conditions ranged from the most favorable to the least favorable; that is, from an abundance of protection to practically none. The survival obtained was undoubtedly very close to that occurring under diverse natural conditions of that winter. It must be emphasized that the winter of 1906–7 was abnormally warm. The average survival in experiments performed in Texas and Louisiana from 1906 to 1911 was 6 per cent, which must represent the average survival occurring in nature. The enormous importance of still further reducing this percentage must be evident.

Emergence from hibernation depends primarily upon temperatures in the spring, although there are other minor factors concerned. Generally, from the first to the middle of March the temperature has become high enough to cause weevils to begin to emerge. Naturally, the individuals under the heaviest protection are affected latest by the temperature. The consequence is that emergence from hibernation is a prolonged process. During one season (1906) it extended from the middle of March to the 28th of June; during another season (1907), from the middle of February to about the 1st of July. During each of these periods there was a comparatively short time—about 10 days, generally in May—of rapid emergence, preceded by an initiatory movement and followed by a period during which the number emerging day by day decreased with rapidity.

HOW NATURE ASSISTS IN DESTROYING THE BOLL WEEVIL.

Although the possible production of offspring in a single season by one pair of weevils has been estimated at 12,755,100, as a matter of fact nature has provided a number of agencies that serve to prevent such excessive multiplication. The most conspicuous of these agencies are heat and insects that prey upon the weevil.

Effects of heat.—When infested squares fall to the ground they may become so heated that the larvæ are killed in a few minutes. The insect in the larva stage can not leave the square, as it has no means of locomotion whatever. Where the infested squares are subjected to the unobstructed rays of the sun the mortality is very high. This explains the well-known fact that dry seasons are unfavorable to the weevil, and indicates great difficulty in controlling the insects in regions where precipitation is heavy. In Louisiana as many as 90 per cent of the immature weevils in cotton fields inspected have been found to be destroyed through this agency. In Texas the mortality from this cause is sometimes even higher. It was found, from examinations in many quarters, that the extent of destruction held a direct relation to the amount of shade. When there was no shade practically all of the larvæ and pupæ were killed outright.

Some of the important means of control to be described later are based upon this consideration.

Insect parasites.—The second of the important agencies provided by nature for the control of the weevil is a large number of insect enemies. These consist of a variety of forms which prey upon the boll weevil. Forty-five species of these enemies are known. Of these, 23 are parasites, which by means of their special organs place eggs on the immature stages of the weevil within the square or boll. The young of the parasite develop by feeding upon the boll weevils, which they ultimately kill. Thus parasites instead of boll weevils emerge from the injured fruit. The parasites seem naturally to be increasing in numbers and effectiveness against the boll weevil. In one instance in 1907 the mortality due to parasites in a field near Robson, La., was 77 per cent. About the same time 61 per cent of the weevils in a certain field near Victoria, Tex., were killed by parasites. These enemies of the weevil have existed in this country for an indefinite time. Their natural habit has been to prey upon weevils more or less related to the boll weevil that have occurred in this country for many years. They never feed on vegetation. It is undoubtedly true that they are now turning their attention from the original hosts, which are generally not very numerous, to the boll weevil, which offers abundant and favorable opportunities for reproduction. Thus they ally themselves with the planter for the protection of the cotton crop.

Other insect enemies.—In addition to the true parasites just described, the boll weevil suffers from a number of insects which are not parasites in a strict sense but prey upon it as food. The principal ones of these predatory enemies are ants. Of these, 12 species are known to attack the weevil. They are the minute brown ants and the yellowish ants that occur frequently in cotton fields and are observed running over the plants or on the ground. Their work is not against the adult weevils, but against the immature stages in the squares. Some species devote their attention principally to the squares that have fallen to the ground, while others habitually seek the insects within the squares that remain hanging on the plants. The larva of the weevil, incased in a thin covering, offers a source of food that the ants are not inclined to overlook. They gnaw through the thin shell inclosing the weevil larva, and the latter is soon destroyed. In some cases more than half of the immature stages in fields have been found to be destroyed by ants alone. To find 25 per cent so destroyed is not a rare occurrence.

Other factors in natural control.—In addition to the principal factors in natural control which have been mentioned there are several of minor importance. Among these may be mentioned that development of plant tissue known as proliferation, which sometimes crushes the immature weevils, and determinate growth, which may prevent the development of the fall broods of the weevil. Attention is also called to the agency of birds in the destruction of the boll weevil, which has been given full attention in the publications of the Biological Survey of this department.

DISSEMINATION.

The boll weevil moves from place to place by flight. Although it is a weak flyer compared with many insects, it has been known to cover a distance of more than 40 miles in a very short time. Its flight can not be prolonged, but successive short flights, especially in connection with favorable winds, often carry the insect to considerable distances. This is the case, however, only during the so-called dispersion period, which extends from about the middle of August to the end of the season. During the rest of the year the weevil is little inclined to fly. There is always a movement from fields in all directions in search of hibernating quarters in the fall and a corresponding movement from such quarters to the cotton fields in the spring. Nevertheless, when the insects reach cotton fields in the spring there is little further movement until the general dispersion begins. Ordinarily between the middle of August and the first of September the weevil seems to be seized with the instinct to migrate. It was thought at one time that this movement was forced by excessive reproduction and took place only when all squares and bolls, or the majority of them, became infested. Investigations have shown, however, that the dispersion takes place frequently when the fields are only slightly infested. In other words, the insect has a well-developed instinct for extending its range into new territory. It is this instinct that has caused the extension of the infested area in the United States year by year. The weevil does not fly in any particular direction except as governed by the wind. If there is no wind, or only a light one, a weevil is as likely to fly in one direction as in another. The individuals carrying the infestation into new regions are those that happen to radiate in the direction of previously uninfested territory.

The fact that the weevil moves about very little except at one season is of great benefit to the planter. As the movement referred to does not begin until after the time when a crop normally is made, it amounts to little after a region has become infested. On the other hand, the limited movement at other times of the year makes it possible for any individual farmer to obtain the best results from his own efforts in fighting the pest. The danger that his efforts will be thwarted by the arrival of weevils from fields where no precautions have been taken is not so important as it is sometimes considered. In fact, it is not important enough to warrant any farmer in deferring action on account of the indifference of his neighbors.

METHODS OF CONTROL.

It will be evident from the preceding statements regarding the life history and habits of the weevil that its control is beset with many difficulties. Its insidious methods of work in the immature stages within the fruit of the cotton plant, the habit of the adult in seeking protection for the greater part of the time under the bracts of the squares, and its enormous power of reproduction and adaptability to new conditions, all tend to place the boll weevil in a class by itself. The difficulties are increased by the necessary procedures in raising cotton. In spite of these difficulties, fairly satisfactory means of control are known. A large share of the reasonable success of the warfare against the pest is due to the assistance furnished by natural agencies, which commonly destroy many more weevils in a cotton field than the farmer could by any known method or methods.

The writer wishes to emphasize the following important points that have a direct bearing upon control:

(*1*) *The weevil has no food plant but cotton.*

(*2*) *The mortality of the weevil during the winter is very high.*

(*3*) *The emergence from hibernating quarters during the spring is slow and prolonged until well into the summer.*

(*4*) *Early in the season, on account of comparatively low temperatures, the development of the weevil is much slower than during the summer months.*

(*5*) *The drying of the infested squares soon destroys the immature stages of the weevil contained therein.*

(*6*) *The weevil is attacked by many different species of insect enemies.*

(*7*) *The weevil has little ability to emerge when buried under wet soil.*

DESTROYING INFESTED PLANTS IN THE FALL.

The process of destroying the infested plants in the fall has been recommended by the Bureau of Entomology and other agencies for many years. It is a step of the greatest general importance, though it can not be applied alike to all regions. It is of the greatest importance in southern localities, where the boll-weevil problem is most serious. In the northern portions of the infested territory it is less important on account of the effect of climatic conditions on the weevil. Its practicability depends upon the supply of labor available and upon the size of the plantings. On the very large plantations in the Mississippi Valley this difficulty is especially marked, but even in that region fall destruction can often be practiced to good advantage. It frequently happens that small portions of the field remain green and attract enormous numbers of weevils after the time when very few are to be found scattered generally in the fields. These areas are generally of such a small size that it is entirely practicable to uproot and destroy the plants growing upon them. The greatest importance of fall destruction is undoubtedly in the southern and southeastern portions of the infested territory, where the cotton fields are small and labor is available for performing the work in ample time.

The object of the fall destruction of plants is the killing of the hordes of adult weevils that are ready to enter hibernation in the fall and the prevention of the development of millions more that would emerge later to pass through the winter. This is accomplished by cutting and burying or burning the infested plants in the fall after the weevils have become so numerous that there is no prospect of the maturity of any additional crop. There are many vital reasons why the wholesale destruction of the weevils in the fall should be practiced wherever possible. Some of these are stated here.

First.—Hordes of adult weevils, many for each plant in the field, are killed outright.

Second.—Many more weevils that are in the immature stages, sometimes as many as a hundred for each plant in the field, are also killed.

Third.—The few adult weevils escaping will be weakened by starvation, and the great majority will not have sufficient strength to pass through the winter.

Fourth. The development of the late broods, which experiments have shown furnish the vast majority of weevils that pass through the winter, is cut off immediately. In this way hundreds of weevils that would develop from each plant are prevented absolutely from so doing.

Fifth. The removal of the infested plants with the weevils facilitates fall or early winter plowing, which is the best possible procedure in cotton raising. Moreover, this plowing assists greatly in the production of an early crop the following season.

In short, in the fall the weevil is at the mercy of the planter as it is at no other time. If the planter desires to kill the insect he can do so. Work in weevil destruction at that time far outbalances all remedial measures that may be applied at all other times of the year.

Many hundreds of cases are on record showing the benefit from the fall destruction of plants in the control of the boll weevil. The process has not been taken up so generally as it should be, but individual instances everywhere show its value. A large amount of experimental work by the Bureau of Entomology has all pointed clearly toward the supreme importance of this essential method in control. In an experiment performed by the Bureau of Entomology in Calhoun County, Tex., the stalks growing on 410 acres of land were destroyed early in October. Careful records kept during the following season showed that this work had increased the production more than one-fourth of a bale per acre over the crop on the check area where such work was not done. Computing the increase in the crop at the current prices, the advantage from the work in the experiment amounted to $14.56 per acre. This was about 29 times the cost of uprooting and burning the plants, as shown by the amount actually paid by the department for the work. Circumstances surrounding the experiment show that the advantage was probably considerably greater than has been indicated here. At any rate, the estimate given is most conservative. In this instance the cotton destroyed was isolated, and the results are perhaps somewhat more conspicuous than would have been the case where there were hundreds of cotton fields in the neighborhood. Nevertheless, experience with fields surrounded by others that have been given no attention has shown a great advantage from taking the proper step in the fall. Of course, concerted action will add to the effectiveness of the work and should be followed in every community.

In addition to the field work by the Bureau of Entomology and by many practical planters, a great deal of work has been done in large cages, where the conditions could be studied most carefully. In this way the exact relative advantage of fall destruction at different dates has been determined. It has been shown in this connection that the earlier the work can be done the better the results will be. For instance, seven times as many weevils survived the removal of the infested plants on November 12 as survived after similar work on October 13.

Mr. J. D. Mitchell, of the Bureau of Entomology, calls attention to a striking example of the value of the fall destruction of the weevils that came to his notice in Texas. On opposite sides of the Guadaloupe River, near Victoria, were two farmers, each having about 40 acres in cotton. In one case the stalks were uprooted and burned in September, and in the other they were allowed to stand until shortly before planting time the following spring. They were equally good farmers, and the soil was the same on the two places. In the first case the crop was 15 bales, and in the other $3\frac{1}{2}$ bales. The work done during the preceding fall plainly increased the crop about fivefold.

No definite rule can be laid down as to the proper time for destroying the weevils upon and in the fruit of the plants in the fall. In general, the proper time is whenever the weevils have reached such numbers as to infest practically all of the squares that are being set. This may occur a month or more earlier in some seasons than in others. Fall destruction as late as November will accomplish much, but several times the number of weevils can be destroyed if the work be done in October. Therefore, the rule should be to destroy the infested plants at the earliest possible date in the fall. It is much better to sacrifice a small quantity of cotton than to defer the operation. The loss will more than be made good by an increase in the next crop.

Objections to the work of destroying the weevils in the fall are frequently raised. The principal one is that the labor supply is insufficient to enable planters to have the crop picked out in time for such fall destruction as is recommended. One of the respects in which the boll weevil will make revolutionary changes in the system of producing cotton is that smaller areas than formerly must be cultivated by each hand. The production can best be kept up or increased by more intensive methods on smaller areas. If this principle be put in operation on plantations in so far as it is practicable, the objection to fall destruction on account of the scarcity of labor will tend to disappear. Another objection raised is that the process tends to impoverish the soil. As a matter of fact, the burning of the stalks removes only a small amount of the fertilizing elements, and, moreover, the practice now is to burn the plants a few months later. The humus is much more important than the fertilizing elements themselves.

In regions where the loss of organic matter from the burning of the stalks is important, the best advice that can be given is to cut the stalks by means of the usual machine for that purpose and bury them deeply as soon thereafter as possible. This will cause the destruction of many of the immature stages in the squares and bolls. The practice will be more effective if the land is harrowed or dragged immediately after the stalks are plowed under.

Where none of the practices recommended can be followed, it only remains for the planter to uproot the plants and leave them lying in the field. This will cut off the development of squares and thereby deprive the weevils of opportunities for breeding, while the plants remain in the field so that picking can be continued as long as may be necessary.

METHODS OF DESTROYING WEEVILS IN THE FALL.

In this connection it may be stated that the proper method, in general, is to uproot the plants by means of plows and to bury or burn them as soon as possible. Other methods are applicable to different conditions. If the plants are to be burned they should be placed in piles or windrows, which will utilize the leaves in the burning. The difficulty in one method of removing the plants—that of cutting them off near the surface of the ground with a stalk cutter or ax—is that during mild seasons many sprouts soon make their appearance to furnish food for weevils that would otherwise starve during the fall or winter. If the ordinary stalk cutter be followed immediately by plows, some of the desired results will be obtained.

The great objection is that the innumerable weevils in the bolls and squares will be allowed to develop. Nothing but uprooting and burning will fully meet the exigencies caused by the weevil, but the burning must be looked upon as an emergency measure especially necessary in regions recently invaded by the weevil and to be replaced by burying after a few years.

Plowing under infested squares.—It has been found that the weevil has little ability to emerge through wet soil. This fact can not be taken advantage of by the farmer during the growing season for the reason that deep cultivation would cause injury to the plants. In the summer or fall, however, when the weevils have become so numerous that it is evident that very little fruit will be allowed to develop, the practice can be followed to good advantage. At such times turning plows should be used, running close to the rows and thereby burying the infested squares deeply in the middles. This practice is of greatest benefit in humid regions, where the rains will soon pack the soil, and on heavy soils. In dry regions and on sandy soil it is of very little value.

Grazing.—In some cases the grazing of the fields with cattle, sheep, or goats can be practiced. This is only a local measure, however, since the supply of live stock in regions where the bulk of the cotton crop is produced is insufficient for the purpose.

Sprout cotton.—A most important result of the proper manipulation of the plants in the fall is that no stumpage or sprout cotton is allowed to grow. The occurrence of such cotton in southern Texas and occasionally in southern Louisiana is there the most important local difficulty in the control of the boll weevil. Sprout plants are sometimes encouraged on account of the production of a small but very early crop. This may have been defensible before the advent of the boll weevil, but at the present time the practice is undoubtedly the worst that could possibly be followed. The sprout plants serve only to keep alive myriads of weevils that could easily be put out of existence by the farmer.

Volunteer cotton.—In addition to stumpage cotton, volunteer cotton, in the strict sense, is of considerable importance in weevil-infested areas. The cotton seed scattered about seed houses and gins frequently gives rise to plants, both in the fall and in the spring, that furnish food and breeding places for weevils. It is needless to call attention to the fact that all such plants should be destroyed. They are merely aids to the enemy.

DESTRUCTION OF WEEVILS IN HIBERNATING PLACES.

After the weevil-infested plants have been removed from the field in the fall the planter can add strength to the blow he has given the insect. As has been stated previously, many of the hibernating weevils are not to be found within the cotton fields or in their immediate vicinity. Nevertheless, most of those remaining in the field can be destroyed, and this is undoubtedly well worth the effort that it will cost. In many cases surprising numbers of weevils have been found hibernating in the trash and rubbish on the ground in cotton fields. In January, 1907, in one instance, 5,870 weevils to the acre were found, of which 70 per cent were alive. This was undoubtedly exceptional, but most of the many examinations made showed more than 1,000 live weevils to the acre in old cotton fields. The insects so found are largely at the mercy of the farmer. He can destroy many by carefully raking up the trash and burning it. Plowing and subsequent harrowing of the land will add to the destruction. This work would be well worth while on general agricultural principles, if no weevils whatever were destroyed. With the weevil present, that farmer invites loss who does not clean the fields to the best of his ability.

Of the multitudes of weevils that fly out of the cotton fields for hibernation, not all are beyond the reach of the farmer. Many are to be found along turn rows, fences, hedges, and old buildings. The cleaning and burning of hedges, fence corners, and in general the removal of trash from the vicinity of the fields will destroy many weevils that would live to assist in the destruction of the crop.

Old sorghum fields, on account of their roughness and the fact that the heavy stubble catches trash moved about by the wind, have been found to furnish very favorable winter quarters for the weevil. The farmer should pay special attention to such fields. They have frequently been found to be the source of the first weevils to damage the cotton in the spring. A little work in the fall or winter will result in the destruction of practically all of the weevils found there. Old cornfields, while not so important as sorghum fields, also furnish favorable hibernating quarters and should be carefully cleared by the farmer who desires to minimize the weevil damage on his place.

A very practical illustration of the danger of trash as aiding in the hibernation of the weevil occurred repeatedly on the experimental farm of the Bureau of Entomology near Dallas, Tex. Across a narrow lane on one side of the experimental cotton field of 40 acres was a small peach orchard in which the weeds were allowed to grow unchecked from year to year. Every season the first weevil infestation in the cotton was found in the immediate vicinity of the orchard. In fact, the infestation always started at that point and radiated into the field. If it had been possible to eliminate the hibernating quarters across the lane—and this meant only the prevention of the growth of weeds—there evidently would have been a considerable reduction in weevil damage, especially early in the season when it was most critical.

LOCATING FIELDS TO AVOID WEEVIL DAMAGE.

The illustration just given emphasizes a method of averting damage by the weevil that can be followed in many individual cases. All planters that have had experience with the weevil know that the portions of their properties near the timber or other locations affording hibernating quarters show the first damage by the weevil and consequently the least production. Of course, it is not always possible to plant other crops in such situations. Nevertheless, farmers frequently can avoid damage by devoting the particular fields known to be most susceptible to weevil injury to other crops. This is not pointed out as a general recommendation. In many cases it would be entirely impracticable, but its importance should be realized by planters in regions where every possible precaution must be taken.

CROP ROTATION.

Save in very exceptional cases the boll weevil never does so much damage on land where cotton follows some other crop as on land where cotton follows cotton. This is due to the fact, as has been pointed out, that the weevils do not fly very far from their hibernating quarters in the spring. Therefore it is evident that a proper rotation of crops may be followed to assist in the fight against the boll weevil. As in the case of the location of the fields referred to, the recommendation here made is no panacea. Nevertheless, rotation can be made to assist in fighting the weevil, aside from the many other advantages that are known to come from it.

PROCURING AN EARLY CROP.

Although the destruction of the weevils in the fall is the great essential step in controlling the insect, it can not be depended on exclusively. The full benefits of the fall work and the maximum crop can not be obtained unless the next great step, procuring an early crop, is taken. In fact, the success of the farmer in producing cotton in regions infested by the boll weevil will depend directly upon the extent to which he combines the various methods described in this bulletin.

There are certain localities where the conditions cause the soil to be late or slow. For instance, the planters on the Red River in Louisiana state that they can procure early crops on their "front" land, but that such is difficult or impossible on the fields back from the river. This is largely a matter of drainage. In some sections in Louisiana and Mississippi the essential step in obtaining an early crop will be largely a question of drainage. Lands so situated that they can not be drained economically to the extent that allows an early crop must be devoted to crops other than cotton.

The advantage of early planting has been demonstrated in every one of the numerous experiments made by the Bureau of Entomology and has now become the general practice among farmers. The reasons for the efficiency of early planting are not far to seek. The small numbers of weevils passing through the winter must have considerable time to multiply. They are unable to breed until squares are put on by the plants, since the food obtained from the fruit is required before reproduction can begin. Moreover, at the time the first squares are put on, the development of the immature stages is comparatively slow, not reaching the very rapid rate that obtains during the warm days and nights of the summer. For these reasons it is possible for the farmer to rush his crop in such a way that a large number of squares and bolls will be formed before the weevils have multiplied to a serious extent. The time it takes the weevils to recover after the rigors of winter, especially after the entirely feasible destruction of multitudes in the fall, can thus be taken advantage of in the production of a crop.

Removal of plants.—One step in the procuring of an early crop is the early removal of the plants, so that the land may be plowed during the fall or winter and the seed bed given thorough and early preparation. The tendency has often been to neglect the cotton fields until spring or at least until "after Christmas." In many cases it would repay the planter many times if he would take the slight additional trouble of plowing the fields before that time. Not only a plowing, but one or more harrowings should be given the land during the winter

In many regions in the South the practice of planting cover crops between the cotton rows is becoming established. This practice should be continued. The cover crops will improve the condition of the soil, and their removal will bring about the best possible conditions for an early crop. Their growth where possible is therefore much better practice than leaving the field unplanted and worked from time to time during the winter.

Fertilizers.—An important step in procuring an early crop under many conditions is the use of commercial fertilizers. In many large areas in the cotton belt the land is not impoverished to the extent that it actually needs fertilizers under normal conditions. It has been demonstrated many times by the different experiment stations in the South that the maturity of cotton frequently can be hastened materially by the use of fertilizers. On impoverished soil fertilizers containing a high percentage of nitrogen give increased yields under boll-weevil conditions.

The proper use of fertilizers is a very complicated matter. In fact, in the light of all present knowledge only the most general rules can be laid down. Each farmer must experiment with the soil or different soils upon his own place and study the results to obtain the greatest benefit from fertilizers at the smallest cost. In the eastern portion of the cotton belt most of the farmers have acquired this experience. In the West, however, this training is lacking. Farmers interested should communicate with the State experiment stations and obtain the latest bulletins regarding experiments with fertilizers in their own regions.

The best method by far of building up soils so that early crops of cotton may be produced is the use of legumes planted either with corn or solid. In the alluvial soils of the Mississippi Valley remarkable results in obtaining increased yields under boll-weevil conditions have followed the growth of cowpeas for a single season. The planting of cover crops is also of great importance and worthy of the careful attention of all planters in the infested territory.

Use of early varieties of cotton.—Fully as important as early preparation and fertilization in obtaining an early crop of cotton is the use of early varieties. The greatest advantage in this instance comes with the joint use of the other expedients recommended for weevil control. By far the best method for obtaining seed of early maturing cotton is for the farmer to carry on the selection himself. In many cases, however, this is impracticable.

The variety to be planted in order to obtain a profitable crop under weevil conditions will depend on a number of factors. The soil, climate, and many other factors must be considered. In many localities it is extremely important to select varieties which are resistant to diseases.

What is needed is a variety which will mature quickly and set a crop by a date not later than the middle of July. In humid regions with heavy infestation the most productive varieties have been found to be King and its principal derivatives, namely, Simpkins and Broadwell. In recommending these varieties the department reminds the planter that they produce lint of a very short staple. Therefore, something of commercial value will be sacrificed. These varieties have small bolls and may safely be replaced by larger-boll varieties in other regions. The Triumph variety is one of the best known for the western portion of the infested territory. The Department of Agriculture has perfected a number of varieties which are useful in weevil territory. Among these are Lone Star, Dixie, Price, Durango, and Columbia. Other varieties which have been cultivated with success are Cleveland Big Boll, Cook's Improved, Rowden, Hawkins, Toole's, and Brown.

Wherever possible the seed should be obtained from local planters who have given attention to varietal selection. Varieties introduced from distant sources require several seasons to adjust themselves to local conditions. The use of seed simply because it comes from a northern locality is a practice which frequently has done great injury. The only case in which the introduction of northern seed is justified is where the seed represents a variety which has been improved with reference to early maturity. Even this practice is not to be recommended except as an emergency measure when locally improved seed is not available.

Early planting.—Another step to be taken in obtaining an early crop, and fully as important as those that have been mentioned, is early planting itself. Naturally no set rule can be laid down as to the proper date for planting. There is much variation in the seasons, and sometimes it is impossible to place the fields in readiness as early as is desirable. Much of the effect of early planting is lost unless the seed bed is in good condition. Rather than plant abnormally early it would be better to improve the seed bed. It is not recommended that planting be made at dangerously early dates. Nevertheless, with proper preliminary attention to the fields it would be possible for farmers in most localities to plant from 10 to 20 days earlier than they are accustomed to at the present time. This, therefore, is the general recommendation that is made. It is much better to run the risk of replanting, provided the seed bed is in good condition, than to defer planting on account of the danger of cold weather. Of course, it is possible to plant entirely too early, so that the plants become stunted during the early days of their growth. It is not intended that planting should be done early enough to have this effect upon the plants.

Cultivation.—During the growing season of the crop the fields should be given very careful cultivations. Most of the benefits of early preparation, early planting, and fertilization may be lost in case the fields are not given the utmost attention subsequently. In case of unavoidably delayed planting the best course to pursue is to cultivate the fields in the most thorough manner possible. Under most conditions the old plantation rule "once a week and one in a row" should be made to apply. This will not result in the direct destruction of many weevils, but it causes the plants to continue uninterruptedly in their growth. By all means such operations as deep cultivation, and cultivation close to the plants, which cause shedding, should be avoided. In many instances a fair crop already set and beyond danger from the weevil has been lost by running the plows so close that the side roots were cut and the plants have shed practically all the fruit. When this happens during the middle or latter part of the season the weevils will certainly prevent the putting on of any more fruit. The general practice of laying by, by scraping the middles with a wide sweep, leaves a hard surface which causes loss of moisture and shedding. Where the weevil occurs, every precaution must be taken to avoid shedding, as the insect will certainly prevent the maturity of the later fruit and, moreover, will be forced to attack bolls which otherwise would not be injured.

Effect of late cultivation.—There are many conspicuous illustrations of the disastrous effects of careless late cultivation. One of these occurred in Louisiana, where some planters in the Red River Valley below Shreveport were making fair crops (in one case 600 bales on 900 acres), while others were making very small yields, as, for instance, in one case 200 bales on 800 acres. Upon investigation it was found that all the planters in the neighborhood were compelled to put all their hands on levee work for five weeks to save their places. During that time the cotton remained uncultivated. After the subsidence of the flood the fields were plowed. Where this work was done carefully, good crops were being produced. In cases where the plows were run too deeply and too close to the plants excessive shedding had taken place, and the weevils prevented the putting on of any more fruit. Careful investigation on several places where the essential conditions were identical left no doubt that the cause of the difference in yields was primarily the difference in summer cultivation.

Occasionally a farmer is found who has obtained better yields on fields where cultivation has been discontinued early. In fact, the writer has seen fields full of grass that were outyielding perfectly clean ones on the same plantation. Such situations have caused erroneous conclusions. As a matter of fact, the explanation is that the late, careless cultivations had done more harm than good. The importance of careful shallow summer cultivations can not be too strongly emphasized.

SPECIAL DEVICES FOR DESTROYING WEEVILS.

The use of an arm or projection that will agitate the cotton plants has been suggested frequently. It was assumed that the knocking of the squares to the ground earlier than they would fall naturally would increase the effect of heat in destroying the immature stages of the weevil. It has been ascertained, however, that throughout much of the territory occupied by the weevil the destruction of the stages in hanging squares is much greater than in those that fall to the ground. For this reason it is evident that the best practice is to allow the squares to hang on the plants as long as they will. In addition to the effect of heat on the immature stages it is important to note that the attack of parasites is much greater in the case of hanging squares. On these accounts our advice is that cross arms or projections on cultivators should not be used except in central and western Texas, where the dryness of the climate brings about a very heavy mortality in fallen squares. In eastern Texas, Arkansas, Louisiana, Mississippi, and Alabama the mortality is greater in the hanging squares, and the planter who causes these squares to fall early merely assists the weevil.

It is sometimes claimed that the use of a crossbar will cause many of the adult weevils to be knocked to the ground, where they will be destroyed by heat. In repeated experiments in jarring and beating cotton plants in which known numbers of weevils were found it was ascertained that very few, if any, left the plants by reason of any agitation that would not break the branches or bark the stems. Occasionally, however, a weevil passing over a leaf is jarred to the ground. Entirely too much stress is often placed upon the importance of jarring the adult weevils to the ground. When specimens are collected by hand and thrown on the surface of the ground, especially if it be finely pulverized, the great majority will be killed almost instantly by the heat. This has caused the mistake on the part of careless observers of supposing that many weevils could be killed by jarring them to the ground. The difficulty, as pointed out, is that it is totally out of the question to jar more than one weevil out of many hundreds to the ground by any process that would not injure the plants severely.

The possibility of controlling the boll weevil by the hand picking of weevils and infested squares has been discussed extensively. The practice is followed by many planters, while perhaps as many others who have tested it have become convinced of its impracticability and have abandoned it.

In order to obtain exact data on hand picking, the Bureau of Entomology has performed many experiments. The original one was conducted on the lower Colorado River, in Texas, on a plantation worked by convict labor, giving the best conditions in the control of labor. No benefit followed thorough pickings twice each week for two months. In another experiment at Gurley, Tex., more than 40,000 weevils were picked on an area of eight acres by paid labor, beginning in April and continuing until July. On the eight acres where this work was done a crop of about 50 pounds per acre in excess of that on other areas was obtained. This was not sufficient, however, to pay for more than a very small fraction of the work done. Later very carefully conducted experiments were performed in northern Louisiana, sometimes in years of great weevil abundance, and sometimes when the insects were comparatively scarce. It was not found that the most thorough hand picking of weevils and squares under supervision was effective in reducing the weevils to the extent that the crop was benefited thereby.

The most important consideration in connection with the hand picking of weevils is the supply of labor. Within the last few years, especially in regions invaded by the boll weevil, the diversification of crops has received a great impetus. Areas of increasing size on most of the plantations are devoted to corn and various forage crops. In the management of these crops considerable labor is required at exactly the same time usually considered proper for the hand picking of weevils and infested squares. It became evident in the work in northern Louisiana that only a very marked benefit from square picking would offset the use of the labor for that work when other operations were requiring attention. As no special benefit followed the picking, there is no basis for recommending the practice, at least where the conditions are similar to those in northern Louisiana. It is possible that in some other regions, where the conditions are different, it may be profitable at times to pick the weevils and squares, but this can be determined only by experiments running through a series of years, as were those in Texas and Louisiana.

It has not been found that mechanical collectors, many of which have been tested, are of any practical value. The most effective mechanical device known is the so-called hoop-and-bag, by means of which the number of weevils taken by each laborer is greatly increased. It was found, however, that this method caused considerable injury to the plants in the breaking of the lateral roots, bringing about shedding and stunted growth.

One point to be considered in this connection is that the occupation of the labor in hand picking may sometimes tend to increase its interest in the crop and improve its morale. This should be given consideration, especially in regions recently invaded by the weevil where the loss of the labor has frequently been much more important than the direct damage caused by the insect. At the same time the planter should not overlook the fact that insistence on square picking may actually disturb the labor and tend to drive it away. For example, the planters in northeastern Louisiana who attempt to follow the practice have had difficulty in preventing their negroes from going to plantations where that arduous labor is not performed.

The following extract from the "Cooperative Extension Work in Agriculture and Home Economics" (S. R. S. Doc. 36, Ext. S.) gives the views of the Demonstration Service of the department concerning the hand picking of weevils and punctured squares:

> In case it is evident that a large number of weevils have been overwintered, it may be advisable to hand pick the early appearing weevils.
>
> Persistent picking and destruction of all punctured squares both from the field and on the ground at least once each week for not less than a month, beginning when the infested squares first begin to drop, is frequently highly advisable. This is a practice of varying importance, depending upon the cheapness with which the work can be done and other factors. It is not usually advisable to continue picking up squares when there occurs very hot and dry weather during June and July, but in case of continued rains or on low, moist soils it offers practically the only hope of controlling infestation. To accomplish material results, the importance of thoroughness and beginning in time can not be overemphasized. Thorough, intensive cultivation should in no event be neglected.

TOPPING OF PLANTS.

The practice of topping plants is sometimes recommended for fields infested by the boll weevil. The results of work by different experiment stations have shown that topping has exceedingly uncertain general results. As often as otherwise it decreases instead of increasing the crop. In any case the topping of plants can probably do no harm in fields that are being damaged by the weevil. It is probable that the general results will be beneficial in causing the more rapid growth of the crop on the lower and middle branches. It has never been possible to demonstrate this in an exact way. Nevertheless, for the general effects stated, the topping of plants is included among the recommendations that should be followed, although as one of minor importance.

COTTON LEAFWORM AND BOLL WEEVIL.

The relation between the leafworm or so-called "army worm"[1] and the boll weevil deserves special attention. A quarter of a century ago the efforts of entomologists and planters were directed toward some means of destroying the leafworm. The use of Paris green was found to be effective. Various changes in the general system of cropping cotton also caused the injuries by the leafworm to become less conspicuous year after year. Even up to the time of the spread of the weevil into Texas, however, poisoning was a more or less regular operation on all cotton farms. The insects never did any considerable damage before the middle or latter part of the season. The reason for destroying the leafworm was that it prevented the maturity of a fall crop. For this reason the saving of the top crop, and in exceptional seasons a part of the middle crop, was all that was desired. The work of the boll weevil has changed all this. After the careful studies that have been given the problem, it is evident that no top crop of cotton can be expected in infested regions. This, of course, reduces the leafworm to an insect of little importance where the boll weevil exists.

The change has actually been even greater than this, for the work of the leafworm has a disastrous effect upon the boll weevil. As has been pointed out in the discussion of fall destruction, the late-developing weevils are the ones that pass through the winter. Consequently, if the leafworms defoliate the plants and stop the formation of squares, a certain degree of fall destruction is accomplished. It can never be as satisfactory as the poorest artificial fall destruction, because the plants continue to leaf out after the defoliation by the worms, thus giving the weevils a supply of succulent food. It is not recommended that the work of the leafworm be depended on in place of fall destruction. Nevertheless, allowing the leafworms to proceed with their work, or even encouraging them, will assist as a

[1] *Alabama argillacea* Hübner.

general procedure against the boll weevil, at least when, for any reasons, the more important steps are not taken. In some cases where the injury by the leafworm begins unusually early, it may still be advisable to check it by poisoning in the well-known manner, but, save in such exceptional circumstances, it will now be better to allow the leafworm to work unrestrictedly.

DESTROYING THE WEEVIL IN COTTON SEED.

It has been abundantly shown that cotton seed is of importance as a medium through which the weevil may be distributed. Many individuals that happen to be carried to the gin on the cotton pass uninjured through the gins to the seed houses. Consequently, every seed house connected with a gin in the infested territory harbors weevils, the number depending upon the amount of cleaning the staple is given. Of course, such seed is exceedingly dangerous when taken into uninfested regions. The present absolute embargoes against cotton seed from the infested region are wise. In general, they should be strictly construed. In some special cases, however, when, for instance, it is desired to obtain special improved seed, proper precaution can be taken to destroy all weevils by means of fumigation with carbon disulphid. The method is as follows:

A tight matched-board box should be provided having sides 4 feet high, open on top, and of other dimensions to accommodate 12 or more 100-pound sacks of cotton seed placed upright upon the bottom. Another tier of sacks could be added if desired. Into each one of these sacks about 1 ounce of carbon disulphid should be forced by an apparatus for volatilizing the liquid and mixing the vapor with air. The accompanying illustration (fig. 6) will give an idea of this apparatus. It should consist of three essential parts, as shown in the illustration. *A* is an air pump having sufficient storage capacity to enable it to maintain a steady discharge of air for several minutes without continuous pumping. The stopcock at a_1 regulates or prevents the escape of air, as may be desired. *B* is an ordinary 2-quart bottle fitted at b_1 with a tight stopper of good length, having two openings, through which the inlet and outlet pipes pass. These pipes may be of glass or metal and should be as large as can be used. The inlet pipe, b_2, reaches nearly to the bottom of the bottle and is provided at the lower end with a perforated metal cap, b_3, as large as will pass through the neck of the bottle. This allows the escape of the air in small bubbles and insures rapid evaporation. The outlet pipe, b_4, reaches only through the stopper. Upon the outside of the bottle is pasted a paper marked with 1-ounce graduations. *C* is a piece of ordinary $\frac{3}{8}$-inch iron gas pipe about $3\frac{1}{2}$ feet long, but this may be any desired length. It is closed and roundly pointed at the tip and for about 15 to 18 inches of its length provided with small perforations pointing in all directions to give free escape to the vapor into all parts of the sack of seed at once.

The connections may be of rubber tubing, but as little rubber as possible should be used for this apparatus, as it is affected by the vapor of the disulphid, and the couplings will have to be replaced frequently. This, however, will not be a considerable item of expense.

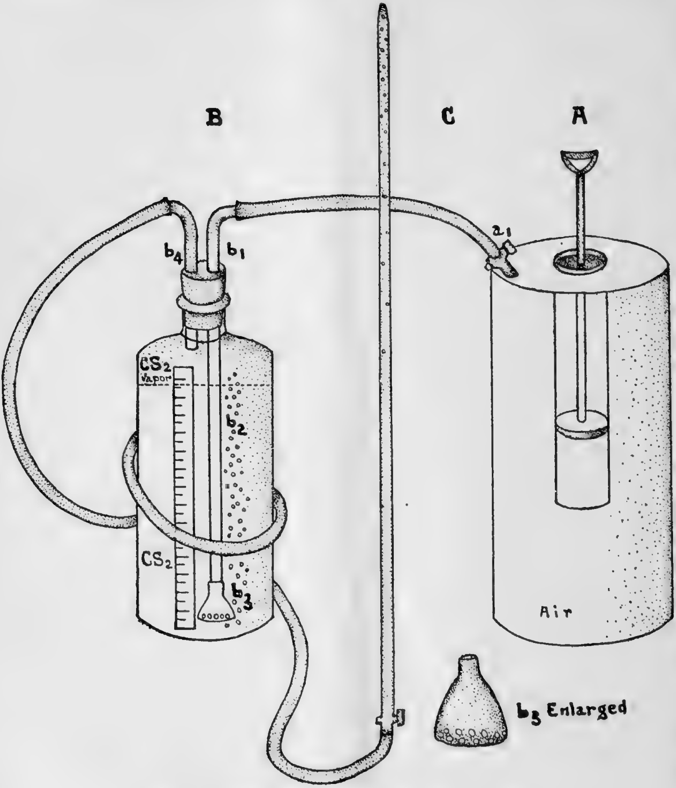

FIG. 6.—Apparatus for fumigating cotton seed in the sack.

With the apparatus just described one operator would be able to accomplish the entire work of disinfection. The amount of carbon disulphid recommended is about 1 ounce for each 3-bushel sack. It requires only from two to three minutes to vaporize 1 ounce of the liquid in the manner described. Fumigation with carbon disulphid therefore can be made effectively at slight expense.

Application of the disulphid in this manner reduces the element of danger to a minimum, as the vapor is almost wholly confined, and the slight quantity escaping, mixed with the open air, would not be in either inflammable or explosive proportions. It has been determined that the slight trace of disulphid vapor in the air would not injure the operator in the slightest degree. The sacks should be left in the box for 40 hours after the gas is injected.

RELATION OF METHODS OF CONTROL OF THE BOLL WEEVIL TO THE CONTROL OF OTHER INSECTS.

The cotton bollworm.—The most important insect enemy of cotton in the United States, aside from the boll weevil, is the bollworm.[1] This pest has existed in this country for many years and frequently reduces the crop very considerably. The annual damage to cotton in the United States has been conservatively estimated at more than $8,000,000. In addition to the injury it does to cotton, this insect is a very important enemy of corn, tomato, okra, cowpeas, and some other crops. Careful studies of the bollworm were conducted by Dr. A. L. Quaintance, of the Bureau of Entomology, in connection with large-scale field experiments in many localities. The conclusions drawn from this practical work were that the essential steps to be resorted to in the control of the boll weevil are exactly the ones that should be followed in the warfare against the bollworm. The following is the statement by Dr. Quaintance on this subject:

> The steps in the production of early cotton, outlined above, include the principal recommendations for the growing of cotton in the presence of boll weevils. It is therefore seen that injury from the cotton bollworm and the cotton boll weevil may be best avoided by the adoption of one and the same course of improved farm practice. The spread of the latter species will render imperative the adoption of these methods in profitable cotton culture, and along with this change the ravages of the bollworm during normal seasons should become less and less.

The cotton aphis.—Of the numerous minor enemies of the cotton plant in the United States there is one, the cotton aphis, or plant-louse, that occasionally may cause unusual damage by reason of early planting. This will happen to any appreciable extent only during wet seasons. Under such conditions the aphis sometimes may make it necessary to replant.[3] Nevertheless, this is not an important matter. It is not of sufficient moment to be considered at all, in view of the enormous benefit in avoiding damage by the boll weevil by means of early planting. If the other steps in the control of the boll weevil be taken, the fields made clean during the winter, and the rubbish in the fence corners and along the

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[1] *Chloridea obsoleta* Fab.

[2] *Aphis gossypii* Glov.

[3] On the contrary, cases have been noticed where early breaking and thorough working caused a lessening in the number of aphids, due to the destruction of the ant that protects them. Mr. Wilmon Newell calls attention to an instance of this kind in Louisiana in 1908.

turn rows destroyed, it is not likely that the aphis will do any considerable damage, even during the coolest and wettest springs.

The injury inflicted by several other insects, such as the cotton-square borer,[1] webworm,[2] and cutworms, often makes the crop somewhat later, and consequently likely to be injured by the weevil.

GENERAL CONTROL THROUGH QUARANTINES.

There is no doubt whatever that the weevil will extend its range to the extremes of the cotton belt in this country in spite of all efforts to prevent it from doing so. The damage is so great, however, and the disturbance of economic conditions so extensive that all reasonable precautions should be taken to prevent the early accidental importation of the weevil to uninfested regions. Practically all of the States in the cotton belt have enactments designed to this end. Undoubtedly they should be enforced to the fullest extent.

At one time considerable inconvenience was caused the shipping interests by the lack of uniform quarantines in different States and the inclusion of articles in which there is very little danger of distributing the weevil. At the present time these difficulties have been largely removed. All that it is advisable to include in the absolute quarantines are cotton seed, seed cotton, cottonseed hulls, and baled cotton. These commodities are likely to carry the weevil with them. In fact, it has been amply demonstrated that the insects are frequently carried in this way. Other articles, and even empty cars, occasionally may transport weevils, but the degree of danger is so much less than in the cases of the articles specified above that they do not need to be taken into consideration.

It is entirely feasible to eradicate small isolated colonies of the boll weevil. An important office of the State authorities concerned in State quarantines should therefore be to investigate reported outbreaks of the weevil and be prepared to take the necessary steps toward eradication at the earliest moment. The Bureau of Entomology will assist the State authorities in any cases of this kind.

ATTEMPTS TO POISON THE BOLL WEEVIL.

From the very beginning of the fight against the boll weevil attempts have been made to poison it. At different times advocates of various poisons have enlisted a considerable following.

Early in the season, before squares are formed, the hibernating weevils feed on the opening leaves of the so-called bud of the cotton plant. At this time it is possible to destroy a considerable percentage by the application of poison. Exhaustive experiments performed by the Bureau of Entomology and other agencies have demonstrated that Paris green can not be used to advantage at this time. More

[1] *Uranotes melinus* Hübn. [2] *Loxostege similalis* Guen.

recent work with powdered arsenate of lead by Mr. Wilmon Newell, formerly of the Louisiana State Crop Pest Commission, seems to show that this poison can be used with profit when the plants are small and the weevils abundant. Experiments performed in Louisiana in 1909 showed that cotton treated with powdered arsenate of lead yielded an average of 71 per cent more than similar cotton which was not treated. For several years the Bureau of Entomology has been experimenting with this poison. In many cases its use has resulted in increased yields more than sufficient to offset the cost of the application. In other cases there has been a loss. It is evident that under some circumstances the poison can be used with profit by the planter. Experimental field work now under way in Louisiana is expected to show the exact practical application of this or other poisons in the control of the boll weevil.

Sweetened poisons.—Many attempts have been made to cause poisoned substances to be attractive to the weevil by introducing sweets and other ingredients. All these have failed completely. Some known sweets, such as honey, have a slight attraction for the weevil, but not enough to assist in practical control, even regardless of their expense.

Contact poisons.—Poisons designed to kill the weevils by suffocating them rather than by being taken into the digestive organs have been proposed. They can not, of course, be effective against the immature weevils within the cotton fruit. The difficulties in reaching the adults are in their manner of work. Normally these insects are found inside the bracts of the squares, where they can not be reached by sprays. In fact, nature designed the bracts to prevent the heaviest rains from reaching the square within. An additional difficulty is in the expense of applying sprays, not only on account of labor, but on account of the special machinery that is necessary. Although there is some very remote possibility that dry poisons may be found of assistance in controlling the weevil, on account of the facts mentioned it is not at all probable that liquid sprays can ever be used.

Effect of confinement.—There is one peculiarity of the weevil that has led to many unwarranted claims as to the efficacy of remedies. The insect will die within a very short time when confined in a bottle or jar, or even in a cage. Even when cages are placed over growing plants it is found that numbers of the insects die and fall to the ground, though no poison has been applied. In many instances experimenters have applied their preparations under such conditions and have found dead weevils later. They have made no allowance for the weevils that would have died under these conditions without any treatment whatever. In such experimental work special pains should always be taken to provide one or more careful checks upon the weevils that have been subjected to treatment.

FALSE REMEDIES.

The extreme seriousness of the boll-weevil problem has called forth many hundreds of suggestions in control. These have covered such methods as changes in manner of planting, attracting the insects to food plants or lights, soaking the seeds to make the plants distasteful, sprays, machines, chemical fumes, and the planting of various plants supposed to be repellent. In many cases these suggestions have been made without due understanding of the habits of the weevil. In other cases practical features, such as the cost of application, have not been considered. The following paragraphs deal with some of the principal fallacious methods that have been proposed.

Late planting.—Foremost among the futile means of control is late planting. At various times different persons have suggested that late planting, especially if following early fall destruction, would so lengthen the hibernating period that no weevils would be permitted to survive. Very numerous experiments in the field and in cages have proved that the weevils in considerable numbers are able to survive from any reasonable time of early destruction in the fall to beyond the date in the spring when any return whatever could be expected from planting cotton, even if the weevils were entirely eliminated. In a field experiment performed in Kerr County, Tex., the plants were removed very thoroughly early in November. Neither stumpage nor volunteer plants were allowed to grow during the winter. There was no other cotton planted within 9 miles. On the experimental field planting was deferred until June 10. In spite of this fact weevils appeared as soon as the plants were up and multiplied so rapidly that the production was not sufficient to warrant picking. Similar experiments carried out under different conditions by the State Crop Pest Commission of Louisiana [1] agree in every way with those obtained by the Bureau of Entomology in Texas.

The reasons for the failure of late planting are evident from a study of the habits of the insect. In many cage experiments it has been found that the last emerging weevils in the spring appear well into the month of June. In fact, emergence has taken place as late as the 27th and 28th of June. Without any food whatever the emerging weevils are able to survive for some time. The maximum known survival of any hibernated weevil without any food whatever after emergence was 90 days, and a considerable number lived from 6 to 12 weeks after emergence. This ability to survive without food, together with the late emergence, renders it entirely out of the question to exterminate the boll weevil by late planting. Moreover, there are always to be found along roads, turn rows, in cotton fields, and elsewhere, a considerable number of volunteer plants,

[1] See Bulletin 2 of the Louisiana Agricultural Experiment Station, published in 1907.

which come from seed scattered accidentally or blown from the bolls during the fall. These plants, starting early in the spring in such numbers as to be beyond control, would furnish a means for the weevils to subsist to the time of planting, regardless of how late it might be. In 1906, for instance, at Dallas, Tex., it was found that volunteer plants appeared in the spring at the rate of about 1,000 per acre. An investigation showed that the number of such plants increases to the westward as the climate becomes drier. Nevertheless, numbers of plants were found near Memphis, Tenn., and Vicksburg, Miss., in a region of more than 50 inches of annual precipitation. Similar observations have been made each season since 1906.

Trap rows.—The idea of attracting weevils to a few early plants or trap rows seemed hopeful at one time. Practical work in the field, however, has shown that nothing whatever can be expected from this method. Before many of the weevils have emerged from hibernation the planted cotton is always large enough to furnish them plenty of food. In practice it has been found impossible to defer planting long enough to concentrate any appreciable number of weevils on the trap plants. Trapping weevils to hibernating quarters is an equally mistaken idea. They can not be induced to resort to any particular places. It is likewise impossible to attempt to make the cotton fields more favorable for hibernation than places outside of the field.

There is one way in which trapping occasionally may be resorted to with good effect. When the plants are destroyed in the fall and the weather is so warm that the majority of the weevils have not entered hibernation, many of them will be found upon the plants that are left. Under these conditions the farmer can leave a few trap rows to good advantage. They should be uprooted and burned within 10 days of the time the other plants are destroyed, to kill the weevils that may be found upon them.

Attraction to lights.—Many insects more or less resembling the boll weevil are attracted to lights. This has caused many persons to attempt to destroy the cotton pest by taking advantage of the supposed habit. It has been found, however, that the boll weevil is not attracted to lights to any extent whatever. In one experiment a number of strong lanterns were placed in cotton fields in Victoria County, Tex. In all, 24,492 specimens of insects were captured, representing about 328 species. Of these, 13,113 specimens belonged to injurious species, 8,262 to beneficial species, and 3,111 were of a neutral character. Not a single boll weevil was found among all these specimens, notwithstanding the fact that the lights were placed in the midst of fields where there were millions of these insects.

Chemical treatment of seed.—It is scarcely necessary to call attention to the fallacy of attempting to destroy the boll weevil by soaking the seed in chemicals in the hope of making the plants that are to grow from them distasteful or poisonous to the insect. Any money expended by the farmer in following this absurd practice is entirely wasted.

Other proposed remedies.—Many remedies for the destruction of the weevil, consisting of sprays, poisons, and fumigants or "smokes," have been proposed. Hundreds of these proposed remedies have been carefully investigated. The claims of their advocates in practically all cases are based upon faulty observations or careless experiments. The strong tendency of the weevil to die in confinement, which has been referred to, has caused many honest persons to suppose that the substances they are applying have killed it. Moreover, an insuperable difficulty that has been encountered in the case of these special preparations is the impracticability of applying them in the field. Hundreds of known substances will kill the weevil when brought in contact with it. The difficulty is to apply them in an economical way in the field. A striking instance of the unwarranted claims of some discoverers of "remedies" for the weevil was the case of a man who demonstrated the efficacy of his preparation by placing a feather in the bottle containing it and applying this to a weevil in his hand. Of course the death of the weevil was very far from a demonstration of the practical working of the supposed remedy. The claims made at different times of the repellent power of tobacco, castor-bean plants, and pepper plants against the boll weevil have no foundation whatever. In fact, none of these plants has the least effect in keeping weevils away from cotton.

Mechanical devices.—Many machines have been constructed to collect the weevils from the plants, or the bolls and squares from the ground. These have consisted of suction and jarring devices. Many of them will destroy a certain number of weevils, but the habits of the insect are such that none has been found to yield results that pay even a small portion of the cost of operation. It is emphasized in this connection that there are plenty of proper ways in which all available mechanical ingenuity may be utilized in the fight against the weevil. There is great need for effective machines for assisting in the destruction of the weevils in the fall, and also for assistance in the cultivation of the crop. The present implements for cultivation, while effective in their way, could be improved in many respects, especially for the purpose of hastening the maturity of the crop. For instance, cultivators to establish a dust mulch rather than to plow the ground are much needed. There are some cultivator attachments, such as the spring-tooth attachment, which are exceedingly useful tools in maintaining a surface dust mulch, but these are not as yet in general use.

SUMMARY OF CONTROL MEASURES.

The following is an outline of the practical methods of controlling the boll weevil described in detail in the preceding pages. These methods are based upon extensive studies and much field experimentation. They represent practically all that is known about combating the most important enemy of the cotton plant. They form a system consisting of several parts. The planter can insure success in proportion to the extent to which he combines the different essential parts.

(1) Destroy the vast majority of weevils in the fall by plowing under or by uprooting and burning the plants. This is the all-important step. It results in the death of millions of weevils. It insures a crop for the following season. If it is not practicable to burn the stalks, they should still be uprooted. This will stop the development of the weevils but allow the cotton to be picked as the supply of labor permits. If the plants can not be uprooted, turning plows should be used in humid regions to cover the fallen squares deeply as soon as the fields become heavily infested in the summer or fall. The practice is of little value in dry regions, but in humid regions it will result in the death of many of the weevils in the buried squares.

(2) Destroy also many weevils that have survived the preceding operation and are found in the cotton fields and along the hedgerows, fences, and buildings. This is done by thoroughly clearing the places referred to. (See pp. 21–22.)

(3) So far as possible, locate the fields in situations where damage will be avoided. This can not be done in all cases, but frequently can be done to good advantage.

(4) Prepare the land early and thoroughly in order to obtain an early crop. This means fall plowing and winter working of the land or the use of cover crops.

(5) Determine the best distances between the rows and between the plants by experiments on local soils. In general, proper spacing for large production before the coming of the weevil will be found most favorable for a large crop.

(6) Insure an early crop by early planting of early-maturing varieties, and by fertilizing where necessary.

(7) Continue the procuring of an early crop by early chopping to a stand and early and frequent cultivation. Do not lose the fruit the plants have set by cultivating too deeply or too close to the rows.

(8) Do not poison for the leafworm unless its work begins at an abnormally early date in the summer.

(9) Do not go to the expense of buying special preparations for destroying the weevil. Disappointment and loss are certain to fol-

low. In case of doubt communicate at once with the Bureau of Entomology or with the entomologist of the State experiment station.

SPECIAL TREATMENT OF SMALL AREAS.

In some cases where, for instance, a farmer has a small area of cotton growing for seed selection, it is practicable to resort to special means of control that would be impossible in general field practice. For the benefit of the many farmers in the infested area who are beginning to improve their cotton by selection, the following suggestions are made: The plat or plats should be far from timber, hedgerows, seed storage houses, and other protection for hibernating weevils. On the appearance of the earliest weevils the plats should be carefully picked over by hand. This should be continued until well after the squares begin to fall. If the falling of the squares continues, it will be found practicable to rake them by hand to the middles or entirely outside of the plats to a bare place, where the sun will soon destroy the larvæ within. Of course, all other general suggestions that are applicable in the field should be added to these special ones.

THE HOUSE FLY

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and

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FARMERS' BULLETIN 851

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology
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THE PRESENCE of flies is an indication of uncleanliness, insanitary conditions, and improper disposal of substances in which they breed. They are not only annoying; they are actually dangerous to health, because they may carry disease germs to exposed foods.

It is therefore important to know where and how they breed, and to apply such knowledge in combating them. This bulletin gives information on this subject. Besides giving directions for ridding the house of flies by the use of screens, fly papers, poisons, and flytraps, it lays especial emphasis on the explanation of methods of eliminating breeding places and preventing the breeding of flies.

THE HOUSE FLY.[1]

CONTENTS.

KINDS OF FLIES FOUND IN HOUSES.

SEVERAL species of flies are found commonly in houses. Some of them so closely resemble the true house fly that it requires very careful observation to distinguish them from it.

One of these is the biting stable fly (fig. 1). It occurs frequently in houses and differs from the house fly in the important particular that its mouth parts are formed for piercing the skin. This fly is so often mistaken for the house fly that most people think that the house fly can bite.

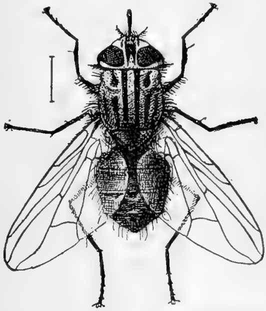

FIG. 1.—The stable fly or biting house fly (*Stomoxys calcitrans*). Much enlarged.

Another frequent visitant of houses, particularly in the spring and fall, is the cluster fly.[2] It is somewhat larger than the house fly, and is distinguished by its covering of fine yellowish hairs. Occasionally this fly occurs in houses in such numbers as to cause great annoyance. It gets its name of "cluster fly" from its habit of collecting in compact groups or clusters in protected corners during cold periods. In the maggot stage it is parasitic on certain angleworms, especially a common greenish colored earthworm.

Another species, which almost exactly resembles the house fly, is the stable fly shown in figure 2. It 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 also are found occasionally in houses. These include the blowfly or meat fly,[3] the blue-bottle (fig. 3) and the green-bottle (fig. 4) flies. They breed in decaying animal matter.

There is still another species, smaller than any of those so far mentioned, which is sometimes called the "lesser house fly."[4] A related

[1] *Musca domestica* L. [2] *Pollenia rudis* Fab. [3] *Calliphora erythrocephala* Meig. [4] *Fannia canicularis* L.

species is shown in figure 5. The "lesser house fly" is distinguished from the ordinary house fly by its paler and more pointed body. The male, which is commoner than the female, has large pale patches at the base of the abdomen, which are translucent when the fly is seen

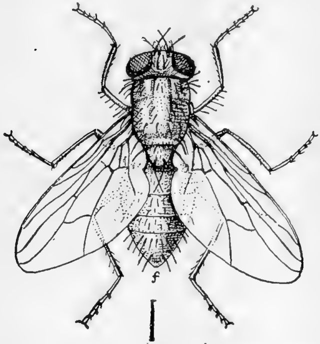

FIG. 2.—A stable fly (*Muscina stabulans*). Much enlarged.

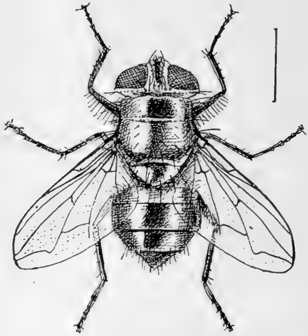

FIG. 3.—One of the blue-bottle flies (*Phormia terraenovae*). Much enlarged.

on the window pane. These little flies are not the young of the larger flies. Flies do not grow after the wings have once expanded and dried. Still another fly, and this one is still smaller, is a jet black species known as the window fly.[1] 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 late summer and autumn many specimens of a small fruit fly, known as the "vinegar fly" (fig. 6), make their appearance, attracted by the odor of overripe fruit.

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 found that the true house fly made up 98.8 per cent of the whole number captured. The remainder comprised various species, including those mentioned above.

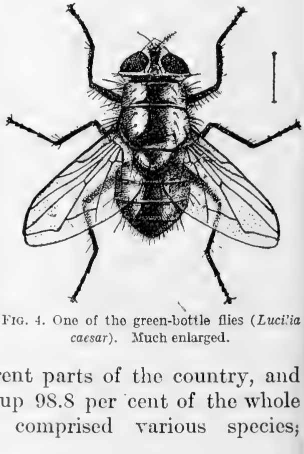

FIG. 4. One of the green-bottle flies (*Lucilia caesar*). Much enlarged.

[1] *Scenopinus fenestralis* L.

WHERE THE TRUE HOUSE FLY LAYS ITS EGGS.

The true house fly (fig. 7), which is found in nearly all parts of the world, is a medium-sized fly with four black stripes on the back and a sharp elbow in one of the veins of the wings. The house fly can not bite, its mouth parts being spread out at the tip for sucking up liquid substances.

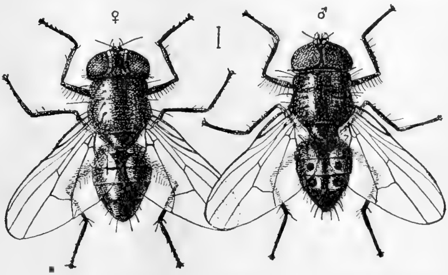

FIG. 5.—A "little house fly" (*Fannia brevis*): Female at left, male at right. Much enlarged.

The eggs (figs. 8, 9) are laid upon horse manure. This substance seems to be its favorite larval food. It will breed also in human excrement, and because of this habit it is very 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 materials,

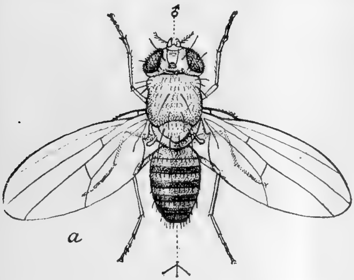

FIG. 6.—The vinegar fly (*Drosophila ampelophila*). Much enlarged.

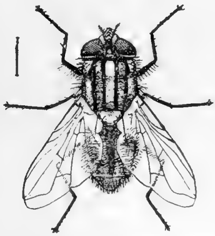

FIG. 7.—The true house fly (*Musca domestica*). Enlarged.

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 little or no horse manure is found, and in such cases it breeds in other manure or in slops or fermenting vegetable material, such as spent hops, moist 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 undoubtedly is 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 are 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 commonly are found in large clusters (fig. 8) in selected places near the top of the pile, where a high degree of heat is maintained by the fermentation below.

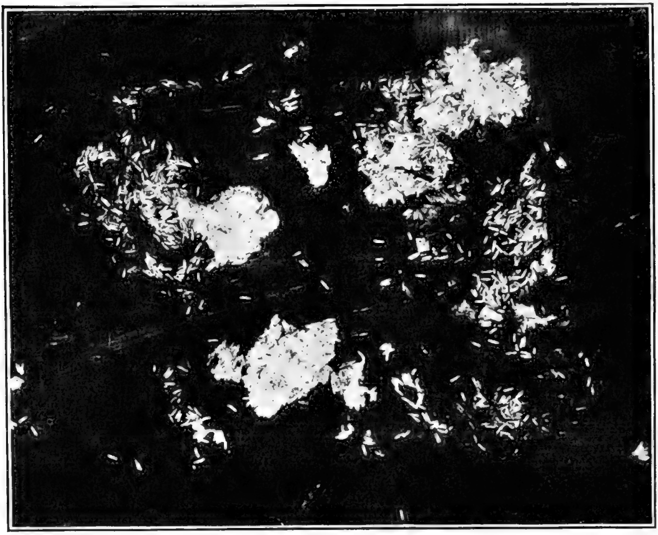

FIG. 8.—Eggs of the house fly. About natural size. (Newstead.)

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, completing the growth of the larva stage in four or five days. The larva period may be prolonged greatly by low temperature or by dryness or scarcity of the larval food. As the larvæ (fig. 10) 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 pupa 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. 11), 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 pupa stage is easily affected by temperature changes and may be prolonged 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 it was found that the time between the emergence of the adults and the first deposition of eggs is considerably shorter than previously was 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 prolonged considerably by the lower temperatures of spring and autumn. In midsummer, with a developmental period of from 8 to 10 days from egg to adult, and a preoviposition period of from 3 to 4 days, a new generation would be started every 11 to 14 days. Thus the climate of the District of Columbia allows abundance of time for the development of 10 to 12 generations every summer.

FIG. 9.—Eggs of the house fly. Highly magnified. (Newstead.)

HOW THE HOUSE FLY PASSES THE WINTER.

The prevailing opinion that the house fly lives through the winter as an adult, hiding in cracks and crevices of buildings, etc., appears to be erroneous. Under outdoor conditions house flies are killed during the first really cold nights; that is, when the temperature falls to about 15° or 10° F. In rooms and similar places protected from winds and partially heated during the winter flies have been kept alive in cages for long periods; but they never lived through the entire winter. In several cases longevity records of from 52 to 54 days were obtained. In other experiments one record of 70 days and another of 91 days was obtained. The average temperature of these experiments varied from 44° to 57° F. The conditions of these experiments seemed to have been most favorable, but flies normally do not seek such places. No uncaged house flies were found during three seasons' observations in unheated and only partially heated attics, stables, unused rooms, etc., where favorable temperature conditions prevailed. The common occurrence in such places of the cluster fly and a few other species, which may be easily mistaken for the house fly, is responsible for the prevailing belief as to the way the house fly overwinters. There is therefore no reliable evidence whatever that adult house flies emerging during October and November pass the winter and are able to deposit their eggs the following spring, although they may continue active in heated buildings until nearly the end of January. On the other hand, there is evidence that house flies pass the winter as larvæ and pupæ, and that they sometimes breed continuously throughout the winter. In experiments at both Dallas, Tex., and Bethesda, Md., house flies have been found emerging during April from heavily infested manure heaps which had been set out and covered with cages during the preceding autumn, this proving that it is possible for them to overwinter as larvæ and pupæ in manure heaps or in the soil beneath such heaps.

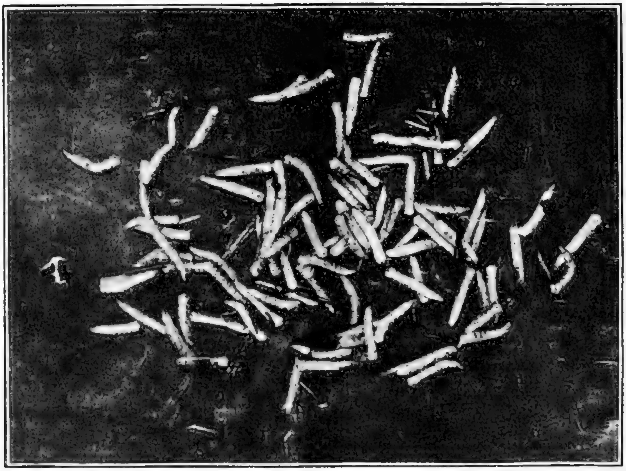

FIG. 10.—Larvæ, or maggots, of the house fly. About natural size. (Newstead.)

FIG. 11.—Pupæ of the house fly. About natural size. (Newstead.)

The second way in which the house fly may pass the winter is by continuous breeding. As is well known, house flies congregate in heated rooms with the approach of the winter season. If no food or breeding materials are present they eventually will die. Where they have complete access to food they may persist as late as the end of January. However, where they have access to both food and suitable substances for egg laying they will continue breeding just as they do outdoors during the summer. Rearing experiments have been conducted in a bakery, in greenhouses, and in animal breeding houses during winter seasons. Even in very cold climates there are undoubtedly many places, especially in cities, where house flies would have opportunity to pass the winter in this manner.

CARRIAGE OF DISEASE BY THE HOUSE FLY.

The body of the house fly is covered thickly 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

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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 subsequently they may contaminate human foods with their feet or excreta or vomit spots, the necessity and importance of house-fly control is clear.

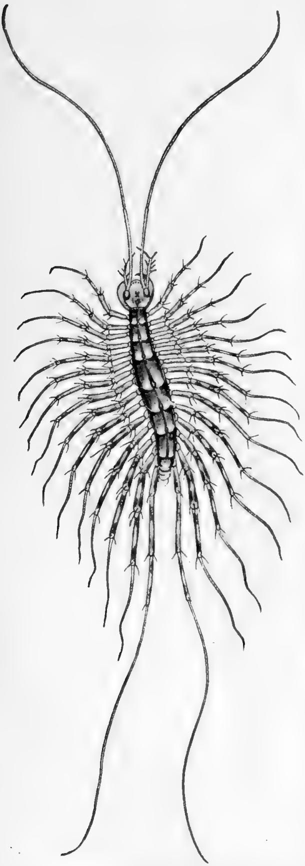

FIG. 12.—The house centipede (*Scutigera forceps*): Adult. Natural size. (Marlatt.)

In army camps, in mining camps, and in great public works, where large numbers of men are brought together 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, such as Asiatic cholera, dysentery, and infantile diarrhea, are all so carried. There is strong circumstantial evidence also that tuberculosis, anthrax, yaws, ophthalmia, smallpox, tropical sore, and the eggs of parasitic worms may be and are carried in this way. 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 OF THE HOUSE FLY.

The house fly has a number of natural enemies. The common house centipede (fig. 12) 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 four-winged wasplike parasites in its larva and pupa condition; and it is destroyed by predatory beetles and ants at the same time.

The most effective enemy of the house fly, however, is a fungous disease,[1] which carries off flies in large numbers, particularly toward the close of the season.

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 protective 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, of course, will 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 AND POISONS.

The use of sticky fly papers to destroy flies that have gained access to houses is well known. Fly-poison preparations also are common. Many of the commercial fly poisons contain arsenic, and their use in the household is attended with considerable danger, especially to children. This danger is lessened by the use of a weak solution of formalin. A very effective fly poison is made by adding 3 teaspoonfuls of the commercial formalin to a pint of milk or water sweetened with a little brown sugar.

The United States Public Health Service recommends a 1 per cent solution of sodium salicylate as almost equally effective. This is prepared by dissolving 3 teaspoonfuls of the pure chemical (a powder) in a pint of water, some brown sugar being added to render it more attractive to flies. A convenient way of exposing these poisons is by partly filling an ordinary drinking glass with the solution. A saucer or plate is then lined with white blotting paper cut the size of the dish and placed bottom up over the glass. The whole is then quickly inverted and a small match stick placed under the edge of the glass. As the solution evaporates from the paper more flows out from the glass and thus the supply is automatically renewed.

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[1] *Empusa muscae.*

FLYTRAPS.

Flytraps may be used to advantage in decreasing the number of flies. Their use has been advocated 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 that thus the possible number of future generations will be reduced greatly.

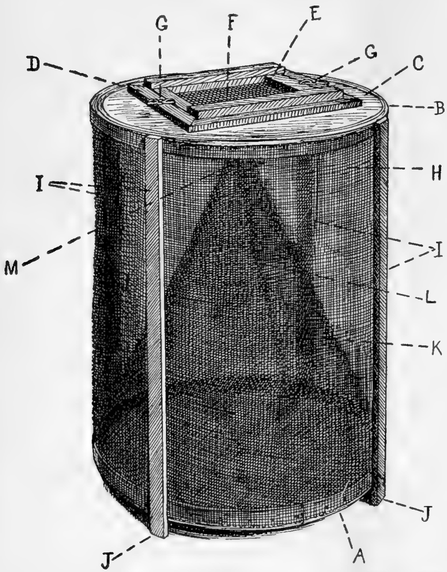

FIG. 13.—Conical hoop flytrap; side view. *A*, Hoops forming frame at bottom. *B*, Hoops forming frame at top. *C*, Top of trap made of barrel head. *D*, Strips around door. *E*, Door frame. *F*, Screen on door. *G*, Buttons holding door. *H*, Screen on outside of trap. *I*, Strips on side of trap between 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. (Bishopp.)

Many types of flytraps are on the market, and as a rule the larger ones are the more effective. Anyone with a few tools, however, can construct flytraps for a small part of the price of the ready-made ones. A trap which is very effective in catching flies and is easily made, durable, and cheap, may be made as follows:

"The trap (fig. 13) 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 $1\frac{1}{2}$ 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 cost of the material for this trap is not great, and in many cases the barrel hoops, barrel head, lath, and strips can be obtained without expense.

"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 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 project 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."[1]

The effectiveness of the traps will depend on the selection of a good bait. For attracting house flies beer is probably the best. It loses much of its attractiveness after the first stages of fermentation are over, and for this reason it should be renewed every day or two. Milk is also a good bait. Overripe or fermenting bananas crushed and placed in the bait pans give good results. A combination of bananas and milk is more attractive than either used separately. A mixture of 3 parts water and 1 part cheap molasses is very attractive after it has been allowed to ferment for a day or two. A mixture of equal parts brown sugar and cheese (or curd of sour milk), thoroughly moistened, gives good results after it has been allowed to stand for three or four days. For catching blowflies and other meat-infesting flies the best bait is the mucous membrane from the lining of the intestines of hogs. Ordinary fish or meat scraps may be used.

PREVENTIVE MEASURES.

Fly papers, poisons, and traps are at best only temporary expedients. The most logical method of abating the fly nuisance is the elimination or treatment of all breeding places. It would appear from what is known of the life history and habits of the common house

[1] Bishopp, F. C. Flytraps and their operation. U. S. Dept. Agr. Farmers' Bul. 734, p. 3–5. 1916.

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, therefore, are 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 for some years has 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. The difficulty has been that manure often becomes infested before it is put into the container, and flies frequently breed out before it is 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.

In order to retain the fertilizing value of manure to the greatest extent it is advisable that air be excluded from it as much as possible and that it be protected 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 to cover these holes with ordinary conical traps, with the legs cut off, so that the bottoms of the traps will fit closely to the box. The same arrangement can be made where manure is kept in a pit.

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 a 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, therefore, is 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 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 is popularly known as Indian polk or itch weed.[1] It is common in wet grounds and is of wide distribution in the United States. The European species of this plant,[2] however, furnishes the bulk of the supply. Hellebore contains a number of chemical compounds known as alkaloids. Alkaloids are organic substances, of which quinine,

[1] *Veratrum viride.*

[2] *Veratrum album.*

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, of course, will give somewhat better results.

Bacteriological studies of the treated piles proved that the bacteria were not injured or 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.

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. Some plants are more sensitive to the presence of borax than others, however, 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 be exercised, in the application of borax, that the manure does not receive more than 1 pound for every 16 cubic feet, and that not more than 15 tons of manure so treated are applied to the acre.

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 recommended that horse manure and other farmyard manures which are to be used as fertilizer 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.

TREATMENT WITH CALCIUM CYANAMID AND ACID PHOSPHATE.

Many experiments with mixtures of commercial fertilizers were tried to determine whether fly larvæ would be killed by any substance the addition of which would increase the fertilizing value of the manure. A mixture of calcium cyanamid and acid phosphate was found to possess considerable larvicidal action. Several experiments showed that ½ pound of calcium cyanamid plus ½ pound of acid phosphate to each bushel of manure gave an apparent larvicidal action of 98 per cent. The mixture in the form of a powder was scattered evenly over the surface and then wet down with water. The use of this mixture adds to the manure the important elements, nitrogen and phosphorus.

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 too expensive when used in amounts sufficient to kill 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 6, that the larvæ of the house fly, when about ready to pupate, show a very strong tendency to migrate, leaving the spot where they have been feeding and crawling 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 is shown in figure 14. The trap was designed by the

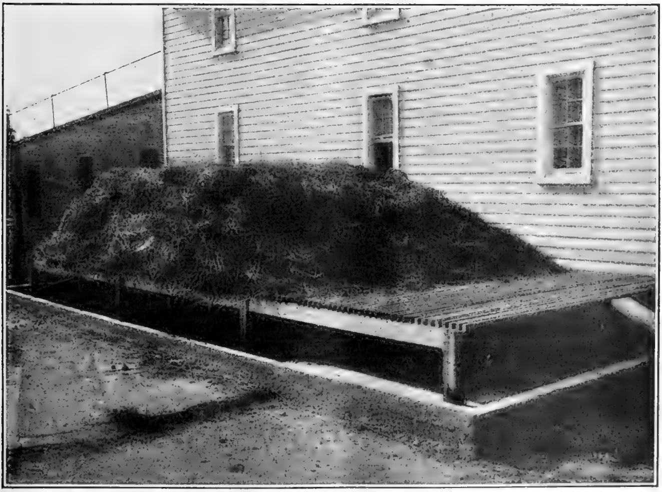

FIG. 14.—A maggot trap for house-fly control. View of the maggot trap, showing the concrete basin containing water in which larvæ are drowned, and the wooden platform on which manure is heaped. (Hutchison.)

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 measures 10 by 20 feet. There are six 2 by 4 pieces running lengthwise 2 feet apart. Across these are nailed 1-inch strips with $\frac{1}{2}$ 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

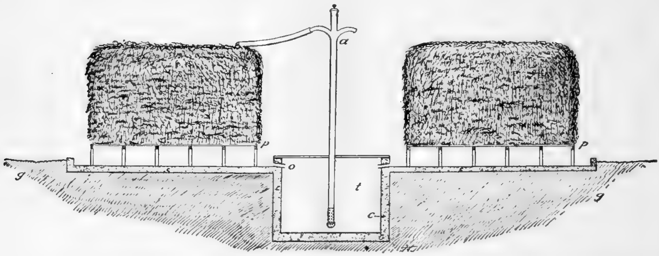

FIG. 15.—Imaginary cross section of an arrangement suggested for use where manure production is large. *a*, Pump; *c*, concrete floor and walls of cistern; *o*, outlet pipes leading from floor of maggot trap to cistern; *p*, platform maggot trap; *t*, cistern for liquid manure; *g*, ground level. (Hutchison.)

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 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 onto 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 onto 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 8 to 10 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 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 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, and from these 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.

COMPACT HEAPING OF MANURE.

Another method of disposing of manure has been recommended by English writers, as a result of experience in preventing fly breeding in the large accumulations of horse manure around army camps. A rectangular area of ground is staked off and the daily accumulations of manure are hauled on to this area, and dumped. It is then built up into a compact heap, the sides of which are straight and beaten hard with shovels. The ground around the edges of the heap is made smooth and hard and then some loose straw is placed in small windrows around the manure pile about 1 foot from the edge. By pressing down the manure into a compact heap, air is excluded from the interior. This condition, together with the high temperature and gases formed by fermentation, tends to make the heap an unfavorable place for the development of fly larvæ. Those which do happen to develop in the surface layers will migrate when fully fed and pupate in the ring of straw around the heap. This straw, with pupæ in it, is swept up every two or three days and burned.

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 measurably 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 of Agriculture Bulletin No. 57, which may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., 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 463 and in Yearbook Separate 712, "Sewage Disposal on the Farm." 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 THE HOUSE FLY.

Antifly crusades have been very numerous in recent years, and some have been noteworthy both in methods and in 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. 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.

PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO HOUSEHOLD INSECTS.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Remedies and Preventives Against Mosquitoes. (Farmers' Bulletin 444.)
Some Facts About Malaria. (Farmers' Bulletin 450.)
The Sanitary Privy. (Farmers' Bulletin 463.)
The Yellow Fever Mosquito. (Farmers' Bulletin 547.)
The Carpet Beetle, or "Buffalo Moth." (Farmers' Bulletin 626.)
The House Centipede. (Farmers' Bulletin 627.)
Cockroaches. (Farmers' Bulletin 658.)
The True Clothes Moths. (Farmers' Bulletin 659.)
The Silverfish: An Injurious Household Insect. (Farmers' Bulletin 681.)
Fleas as Pests of Man and Animals, with Suggestions for Their Control. (Farmers' Bulletin 683.)
Hydrocyanic-acid Gas Against Household Insects. (Farmers' Bulletin 699.)
House Ants: Kinds and Methods of Control. (Farmers' Bulletin 740.)
The Bedbug. (Farmers' Bulletin 754.)
White Ants as Pests in the United States and Methods of Preventing Their Damage. (Farmers' Bulletin 759.)
Carbon Disulphid as an Insecticide. (Farmers' Bulletin 799.)
A Maggot Trap in Practical Use: An Experiment in House-Fly Control. (Department Bulletin 200.)
Further Experiments in the Destruction of Fly Larvæ in Horse Manure. (Department Bulletin 245.)
Argentine Ant: Distribution and Control in the United States. (Department Bulletin 377.)
European Earwig and Its Control. (Department Bulletin 566.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

The Migratory Habit of House-Fly Larvæ as Indicating a Favorable Remedial Measure. An Account of Progress. (Department Bulletin 14.) 1914. Price, 5 cents.
Experiments in the Destruction of Fly Larvæ in Horse Manure. (Department Bulletin 118.) 1914. Price, 10 cents.
Fleas. (Department Bulletin 248.) 1915. Price, 10 cents.
Termites, or "White Ants," in the United States: Their Damage and Methods of Prevention. (Department Bulletin 333.) 1916. Price, 15 cents.
Notes on the Preoviposition Period of the House Fly. (Department Bulletin 345.) 1916. Price, 5 cents.
Experiments during 1915 in the Destruction of Fly Larvæ in Horse Manure. (Department Bulletin 408.) 1916. Price, 5 cents.
Principal Household Insects of United States, with Chapter on Insects Affecting Dry Vegetable Foods. (Entomology Bulletin 4, n. s.) 1896. Price, 10 cents.
Notes on Mosquitoes of United States, Giving Some Account of Their Structure and Biology, with Remarks on Remedies. (Entomology Bulletin 25, n. s.) 1900. Price, 10 cents.
Economic Loss to People of United States Through Insects that Carry Disease. (Entomology Bulletin 78.) 1909. Price, 10 cents.
Preventive and Remedial Work Against Mosquitoes. (Entomology Bulletin 88.) 1910. Price, 15 cents.
Argentine Ant. (Entomology Bulletin 122.) 1913. Price, 25 cents.

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CONTROL OF DISEASES AND INSECT ENEMIES OF THE HOME VEGETABLE GARDEN

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FARMERS' BULLETIN 856
UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief
and the
Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. November, 1917

Show this bulletin to a neighbor. Additional copies may be obtained free from the Division of Publications, United States Department of Agriculture

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1917

THIS bulletin contains directions for the control of the most common insects and diseases of the home vegetable garden.

Preventive measures are best. Rotate crops. Avoid introducing insects and diseases on plants obtained for setting out. Practice clean cultivation. Employ fertilizers to stimulate plant growth. Work on the principle that a vigorous growing garden will produce a crop in spite of injurious insects and diseases.

Become familiar with the insects and diseases known to occur in your district on the crops you are growing. Equip yourself in advance with all necessary remedies and the means of applying them. Remember that the timely application of a remedy acts as an insurance against loss.

Watch constantly for the first appearance of a disease or insect. Inspect the garden at least every other day. Determine what is causing injury and apply the proper treatment promptly. Use the combination treatments in case a complication of troubles is present. Repeat treatments as often as necessary, keeping in mind the influence of weather conditions as well as the life history of the insect or fungus causing the disease.

Use insecticides and fungicides in the proper dilution to accomplish the object without injuring the plants. Standard remedies are best. Test others experimentally before using them on a large scale.

Use the best sprayers. A thorough application is necessary for the best results. Adjust the sprayer so that all parts of the plant that are exposed to the air will be covered.

Work for cooperation in the neighborhood. One badly infected or infested garden may be the source of disease infection or insect infestation for several near-by gardens. Keep your own garden clean and it will be an object lesson for careless neighbors and will have a tendency to help clean up the neighborhood. This will make control easier and cheaper another year.

CONTROL OF DISEASES AND INSECT ENEMIES OF THE HOME VEGETABLE GARDEN.

CONTENTS.

PLANT DISEASES AND INSECTS.

FROM the time the seeds of garden crops are put into the ground until the crops are harvested a succession of diseases and insect enemies may appear, each of which must be fought by the methods that experience has shown to work best in the particular case.

Diseases of plants are due to many causes. Plants suffer if the soil is not suited to them. It may be too rich or too poor or too heavy or too light, or it may contain too much or too little water. It may lack lime and humus. Some vegetables, such as spinach and cauliflower, thrive in cool weather and do poorly in midsummer, while others, like tomatoes and Lima beans, are hot-weather plants. Excessive heat produces wilting or tipburn. Too much water in the soil keeps from the roots the air they need and causes a sickly, yellow growth. Fertilizers used carelessly or in excess may burn the leaves, injure the roots, or prevent seed from germinating.

It always is important to have the soil deeply plowed or spaded and made loose and light with plenty of well-rotted manure or compost and to keep the ground cultivated so that the surface will not become hard or weedy. Use the best seed to be had and sow it liberally to get a good stand, but thin out the plants, as overcrowded plants are in much greater danger of becoming diseased than those that receive plenty of air and sunshine.

The diseases which cause most loss are due to fungi and bacteria and will be referred to often in the bulletin. Fungi and bacteria are plants, though usually exceedingly small. The disease-producing forms live on or in our vegetables and fruits, feeding on them and causing the various blights, rots, and spots of which we complain.

Fungi and bacteria grow and multiply rapidly when conditions suit them. Instead of seeds they form spores, which are minute bodies produced in great numbers, to be spread by wind, water, or other agencies, and, like seeds, these spores may germinate, grow into a plant or fruit, and start a new center of disease.

The weather has an important influence on the development of fungous diseases, moisture and warmth being necessary.

True insects are small creatures which in the adult stage have rather hard bodies divided into three portions, head, thorax (chest), and abdomen (belly). They have a single pair of antennæ, or "feelers," normally three pairs of legs, and usually one or two pairs of wings. Among injurious forms of true insects are beetles, butterflies, moths, sawflies, ants, flies, grasshoppers, plant-bugs, thrips, and plant-lice.

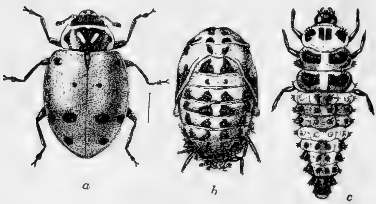

FIG. 1.—The convergent ladybird (*Hippodamia convergens*), an enemy of garden insects: *a*, Adult; *b*, pupa; *c*, larva. Enlarged.

Other small creatures in a general way are popularly classified as insects, such as sowbugs, red spiders, mites, and thousand-legged "worms," or millipedes.

Insects are classified into (1) chewing or biting forms, which devour leaves and other portions of plants; and (2) sucking forms, which injure and destroy plants by draining their vital life juices. For the first class, arsenicals are the best remedies; for the second class, contact poisons are used.

Gardeners should learn to know the insects which are useful in destroying injurious insects. Prominent among these is the convergent ladybird (fig. 1). It destroys not only all forms of garden plant-lice but the eggs of various insects, such as the Colorado potato beetle. Other beneficial insects are wasps, ichneumon and chalcis flies (minute, wasplike insects), ground beetles, soldier bugs, syrphus flies, tachina flies, and lace-wing flies. Were it not for the natural enemies of the potato beetle and of cabbage worms, army worms, and similar pests, all vegetable crops probably would be failures.

PREVENTION OF DISEASES AND INSECT INFESTATION.

The gardener who starts with a clean soil may do much to keep insects and diseases out, and thus save the trouble and cost of applying sprays. Prevention is better than cure, especially in the home garden, which usually must be planted on the same ground year after year.

Some of the worst garden troubles are brought in on the roots of plants and remain in the soil to attack the next crop. So in buying plants of any kind one should be sure that they are healthy and free from insects. The roots should be clean and fibrous, not swollen or knotted. Southern gardeners in particular should be on the watch against root-knot (fig. 2). Cabbage and cauliflower plants should be inspected for clubroot (fig. 3), and sweet-potato plants for black-rot (fig. 4). Irish potatoes should be treated for scab before planting.

FIG. 2.—Root-knot on lettuce. Similar galls are formed by this pest on the roots of nearly all vegetables.

CONTROL INSECTS THAT SPREAD PLANT DISEASES.

Many insects not only attack the crops directly but also carry plant diseases. Thus, the striped cucumber beetle spreads the wilt of cucumbers, squashes, melons, and related plants; plant-lice carry the cucumber mosaic; the potato flea-beetle, the bacterial wilt; and various other insects occasionally carry spores from diseased to healthy plants.

AVOID WOUNDING PLANTS.

In cultivating or working around plants, avoid wounding or breaking them. In pruning, make a clean, close cut. In harvesting fruits and vegetables that are to be stored, handle with the greatest care to avoid bruising, as decay most frequently begins where the natural protective covering is broken. Certain insects, such as the potato tuber moth, also gain access at such points.

SANITATION.

Neatness, cleanliness, and order in the garden help in the fight against insects and diseases. As a general rule, the residue of the garden, such as cornstalks, potato tops, etc., are to be turned under to improve the soil. Do this promptly, so that insects and disease spores may not be harbored by the rubbish. In some cases, which will be pointed out later, diseased vegetable remains should be taken out of the garden and burned. Weeds in the garden and around it harbor both insects and diseases, particularly if the weeds are related to the cultivated plants. Plant-lice, red spiders, and other insects invade the garden from neighboring weed borders. Cabbage pests live on wild mustard, shepherd's-purse, and related weeds. Just as soon as any crop is gathered, spade up the ground, bury the old remains deeply, and plant something else. Except in the extreme North, rye or oats can be sown to give winter cover.

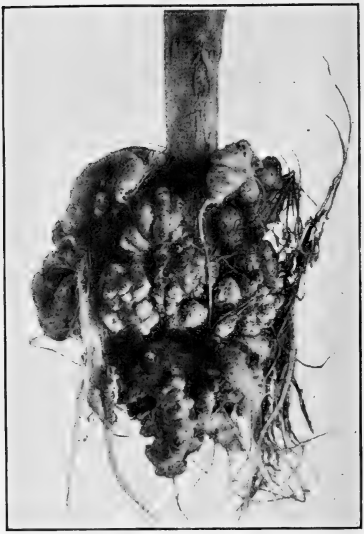

FIG. 3.—Clubroot on cabbage. This attacks turnips and related plants in the same manner.

CROP ROTATION.

Farmers have found that by rotating their crops they reduce the injury from plant diseases and insects and also increase the fertility of the soil. This principle applies to the home garden, where, if possible, it will be better to make a new plan each year, placing each vegetable where some other grew the year before—peas on the old tomato ground, beets and carrots after the corn, etc. The details of this rotation must vary in each case according to the climate, soil, and vegetables grown and the diseases and insects to be guarded against.

FORMULAS FOR FUNGICIDES AND INSECTICIDES.

BORDEAUX MIXTURE.

Bordeaux mixture is used for the control of fungous diseases of many vegetables and fruits and as a deterrent of flea-beetle attack. It can be purchased in convenient package form from seed dealers or prepared at home from bluestone (copper sulphate), which costs 10 to 25 cents per pound, and fresh stone or lump lime (quicklime).

Bluestone ounces	4	or	Bluestone pounds	4
Quicklime do	4		Quicklime do	4
Water quarts	12		Water gallons	50

Dissolve the bluestone in a wooden or earthenware vessel, using hot water. Dilute with half the water. Do not use tin or other metal containers, as they would be spoiled. Slake the lime by adding water, a little at a time. When reduced to a milky fluid, dilute with the rest of the water and strain through doubled cheesecloth or a brass wire strainer of 18 meshes per inch and pour into it the bluestone solution. Stir well and apply at once. This is best when prepared fresh for each using.

Usually it is difficult to get fresh lime at short notice, as needed. To save trouble, the owner of a small garden may weigh out at one time several 4-ounce lots of lime, perhaps as many as he expects to use during the summer, slake them in old glass jars, cover with water, and set them away. The lime will remain in good condition as long as it does not become dry, and each jar is sufficient to use in making a pailful of Bordeaux mixture, or one filling of the average small sprayer. Those who have to spray large fields or orchards should consult Farmers' Bulletin 243.

FIG. 4.—Black-rot on sweet potato. Plants showing blackened discolorations on the underground parts should be discarded.

BORDEAUX MIXTURE WITH RESIN FISH-OIL SOAP.

Resin fish-oil soap is added to the Bordeaux mixture to make it stick to plants, especially those with smooth leaves.

Add to the foregoing formula resin fish-oil soap, two-thirds of an ounce to 1 ounce per gallon. It is necessary to add water to the soap a few drops at a time, stirring well until the sticky soap is dissolved. This soap can be purchased of most dealers in garden supplies.

CARBOLIC-ACID EMULSION.

Carbolic-acid emulsion is a good remedy for certain root feeders, such as root-maggots, which are injurious to onions, cabbages, turnips, beans, and similar plants, to protect against the fly or adult depositing eggs. Its value for other purposes is somewhat limited. It is prepared by mixing half a pound of soap in half a gallon of water and 1 quart of crude carbolic acid, or phenol, and is then diluted with about 25 parts of water. It should be applied a day or two after the plants are up, and, in the case of transplanted crops, a day after they are transplanted, and should be repeated if necessary.

Carbolic acid acts as a repellent and is a contact and stomach poison. It is corrosive and should be handled with care.

CORROSIVE SUBLIMATE (MERCURIC CHLORID).

Mercuric chlorid (corrosive sublimate) is used for treating seed potatoes and cabbage seed for diseases. It may be purchased at drug stores in the form of tablets costing about 25 cents for 24. Dissolve two large tablets in a quart of water to make a 1 to 1,000 solution. For larger quantities use 2½ ounces to 15 gallons of water. *Corrosive sublimate is a deadly poison.* It attacks metals and therefore must be used only in a wooden, glass, or earthenware vessel.

FORMALDEHYDE (FORMALIN).

Formaldehyde (formalin) is used for treating seed potatoes, seeds, and soil, to prevent diseases. This is a clear solution of 40 per cent formaldehyde gas in water, which retails at about 50 cents per pint. It is very irritating to the eyes and to cuts, but not poisonous. It does not attack metals. Use 1 teaspoonful to a teacupful of water, 1 ounce to 2 gallons of water, or 1 pint or pound to 30 gallons of water (for potatoes and onions). It is not an insecticide.

KEROSENE EMULSION.

Kerosene-soap emulsion is a remedy for most sucking insects.

This is made by combining 1 gallon of kerosene and one-fourth pound of laundry soap, or 1 pound of whale-oil (fish-oil) or other soap, or 1 pint of soft soap, with half a gallon of water. The laundry soap, if dry, is shaved and dissolved in boiling water and then poured (away from the fire) while still boiling hot into the kerosene. The mixture is then churned rapidly 8 or 10 minutes, the liquid being pumped back upon itself by means of a sprayer with a nozzle throwing a strong, solid stream. At the end of this time the mixture has become a thick cream—the stock emulsion. In the preparation of the emulsion a sprayer is a necessity, since if it is not made as directed a perfect emulsion will not be formed. If properly prepared, this stock emulsion will keep through a season and is to be diluted only as needed for use. For most species of sucking insects 1 part of the stock emulsion should be mixed with 15 parts of water. It is then applied with a fine nozzle in the form of a mist spray or like a dense fog, and is sprayed only long enough to cover the plants.

If the spray is not applied properly it may drip off the leaves, causing the ground beneath to become soaked. As a result delicate plants when exposed to direct sunlight may be injured or killed. For this reason nicotine sulphate is preferable.

LEAD ARSENATE.

Paris green, formerly much recommended for biting and chewing insects, such as the Colorado potato beetle, cucumber beetles, cabbage worms, and tomato hornworms, because it was known to most farmers and is for sale at drug stores, is being superseded to a considerable degree by other arsenicals, of which the most important is arsenate of lead, or lead arsenate.

The present high cost of all copper compounds has resulted in a similar high price for Paris green. Although arsenate of lead has also risen in price it is less costly and is preferable for the following reasons: (1) It serves the same purpose as Paris green against external leaf-eating insects and certain other chewing insects; (2) it is applied in the same manner; (3) it is less harmful to growing plants, being less likely to burn delicate foliage; (4) it adheres better to the foliage; (5) it is less troublesome to prepare; and (6) the white coating which it leaves on the plants after spraying shows which plants have not been reached by the treatment.

Lead arsenate, however, does not kill insects as quickly as Paris green, although the fatal dose is absorbed nearly as soon.

Arsenate of lead is sold in both powder and paste forms. At the rate of 2 pounds of powder or 4 pounds of paste to 50 gallons of water or Bordeaux-mixture solution it will destroy cabbage worms and most other caterpillars, the "slugs" and adults of the Colorado potato beetle, cucumber beetles, and most other insects of this nature.

In small gardens two-thirds of an ounce of the powder form, or 10 level teaspoonfuls, to 1 gallon of water is used.

Generally, the adhesiveness of lead arsenate is enhanced by the addition of a "sticker" of about the same amount by weight of resin fish-oil or other soft or dissolved soap as of the arsenical used. This must be used in the case of cabbage and similar crops, since otherwise the waxy bloom of the foliage repels the liquid, causing it to gather in large drops, and a thorough distribution, on which the success of the treatment depends, is not secured. If properly applied, the leaves should show a thin white coating of the poison for a long time.

The number of sprayings to be applied will depend on the insect concerned in the injury and on local and seasonal conditions. Sometimes a single application at the proper time will suffice, although two or three are required for the cabbage worm, potato beetle, and certain other insects which produce more than one generation annually.

LIME.

Lime is used to control cabbage clubroot. It neutralizes soil acidity and therefore tends to increase scab on potatoes. It acts at the same time to a limited extent as a deterrent against certain insects which may be in or on the soil, such as maggots and grubs, and is a good remedy for slugs. Air-slaked or hydrated lime is the best form to use.

GAS LIME.

Gas lime is particularly valuable against certain underground insects. It may be placed between the rows of some crops, but as a general rule should be used after the crop is off. It is a refuse or by-product of gas-manufacturing plants and is simply lime through which the illuminating product has passed in the primary stage of purification. It may be obtained frequently for the mere cost of hauling. It is highly impregnated with gas and tarry substances when perfectly fresh, giving out a strong odor for several days after being applied. It should be remembered that it will kill plant life as well as insects, and it is best to use this on a small scale before employing it extensively.

LIME-SULPHUR.

Lime-sulphur is a valuable spray for fruit trees, but not suited for use on vegetables. Experiments have shown that potatoes are injured rather than benefited by it.

NICOTINE SULPHATE.

For small garden plats 1 teaspoonful of nicotine sulphate should be used to 1 gallon of water, to which a 1-inch cube of hard soap should be added and thoroughly mixed. If a larger quantity is desired, use 1 fluid ounce to 8 gallons of water, with the addition of one-half pound of soap. Full directions are given on the covers of the packages, and instructions accompany them.

For large forms, like the pea aphis, the nicotine should be used slightly stronger, and for small kinds, like the spinach aphis, it may be used considerably weaker.

The following nicotine-spray formula will be found the best for the average aphis or plant-louse on truck crops, as well as for thrips:

Nicotine sulphate (40 per cent) pint	$\frac{3}{8}$
Soap (dissolved) pounds	2
Water gallons	50

This formula gives 1 part nicotine sulphate to 1,000 parts of water.

The quantity of soap required will vary with the quality of water, more soap being required in "hard" water; but on the average the proportion specified in the formula will give satisfaction. An examination of a freshly sprayed vine will show whether there is sufficient soap in the mixture. If the spray draws together in drops and leaves part of the foliage dry, more soap should be added. Where possible, fish-oil soap should be used, but if it can not be procured, cheap laundry soaps will do. The composition of the cheap soaps is variable, and if too much soap is used, some injury may result to tender foliage.

In the use of nicotine sulphate the effective application of the spray is of the utmost importance, since it is primarily upon this that the success or failure of the treatment depends. If the liquid has stood for any length of time it should be agitated thoroughly before use. The insects themselves must receive a thorough coat of the spray or they will not be killed, and immediate inspection after spraying should show the foliage occupied by the insects to be completely wet.

Spraying should be done as early as possible, *always on the first appearance of the insect*, not only because it is good practice to keep the plants free from pests, but because more thorough work can be done on small plants.

SOAP PREPARATIONS.

Soaps of most kinds are of value in solution as washes and as sprays in the control of certain noxious insects. Both hard and soft soaps are employed, and so-called whale-oil soaps, usually manufactured from fish oil, are of great value and much used. Among these are cresol soap and resin fish-oil soap. Such soap is usually prepared by dissolving 1 pound in 4 to 10 gallons of water. On some hardy plants a solution of 1 pound of soap to 2 gallons of water can be used, but this strength is harmful to delicate plants and must be used with caution. The best strength for ordinary plants is about 1 pound in 6 to 10 gallons of water, applied as a spray. It is of most value against plant-lice, minute leaf-bugs, leafhoppers, and thrips, and against some forms of small soft-bodied and sensitive insects and their young. Soaps possess no particular advantage, however, over nicotine sulphate or kerosene-soap emulsion, but are easier to prepare than the latter.

Neutral soaps of the Castile type are much used on plants grown under glass and as a means of checking the ravages of plant-lice, thrips, red spiders, and some other forms of small insect pests. They are particularly valuable against many insects which obtain their food by suction.

HOMEMADE SOAP.

Homemade soap can be prepared by following the directions printed on cans of lye for household use. It will save considerable expense, and those engaged in gardening can do this work at odd times or when the garden is wet with rain.

SULPHUR.

Sulphur is used for mildews. Use the finest flour sulphur obtainable. A special grade is made for dusting plants. Sulphur compounds are valuable for the red spider and for some other forms of mites, but they should be followed by syringing or spraying with neutral soap solutions or water.

MECHANICAL METHODS OF CONTROL.

For garden insects there are several control methods that do not require the use of insecticides, but too much must not be expected from them. Of these hand picking is useful for large, comparatively inactive insects such as the potato beetle, cutworms and other caterpillars, and the squash bug. Another method is jarring or beating insects from low plants into large pans of water on which a thin scum of kerosene is floating. The water prevents the insects from escaping, and the kerosene, being on the surface, kills the insects with which it comes in contact. Collecting nets are valuable for some pests; for example, the tarnished plant-bug. Brushing by different means is used to a considerable extent and consists in beating or brushing insects from the plants with pine boughs or similar brush. This method has proved of great value in combating the pea aphis. Covering with cloth is of use as a preventive for the striped cucumber beetle when the cucumbers are quite small, and for root-maggots. Trapping by different methods with old boards is useful for squash bugs and cutworms. Poisoned baits may be placed under such traps. Plowing, disking, and harrowing all can be done by hand and are of considerable service.

SPRAYING METHODS.

To be successful in the control of insects and diseases, spraying must be done promptly and thoroughly. Spraying with Bordeaux mixture should be done before rains rather than after, provided the spray has time to dry on the leaves. Where the advice on later pages is to "repeat spraying every 7 or 10 days," these intervals should depend on the weather. If it is rainy or muggy, with fogs or heavy dews, spray frequently to keep the foliage protected at all times. If dry, a longer time may be allowed.

FIG. 5.—An atomizer sprayer.

The ideal spray is a fine mist, and the best work is done when the plant is thoroughly and evenly covered with fine drops. Stop spraying before the foliage is drenched.

The higher the pressure, the better the spray.

Clean all sprayers each time after using.

For delicate foliage, spray after this gets under shade. Hot sunlight is dangerous with many sprays, such as kerosene emulsion.

SPRAYING AND DUSTING APPLIANCES.

The materials recommended herein may be applied in various ways.

For the small garden an atomizer sprayer, such as is shown in figure 5, is good, but a better sprayer for gardens of small and medium size is illustrated in figure 6 and on the title-page. In the case of the atomizer sprayer it is an advantage to have the container for the liquid made of glass, as Bordeaux mixture and other materials attack tin and iron. These sprayers cost from 50 to 75 cents. A similar but more durable and effective sprayer made of brass costs $1.25.

Compressed-air sprayers may be had in galvanized steel at $3.50 to $5, and in brass at $6.50 to $12.50. Bucket sprayers such as the one shown in figure 7 range in price from $2.25 to $5. To do good work with them, however, two persons are required.

Really efficient sprayers are expensive, but if well cared for will last many years. Neighborhood cooperation may solve this problem. If a number of garden owners club together to purchase a sprayer, it is advised that a barrel pump on a hand cart be secured, or the bar-

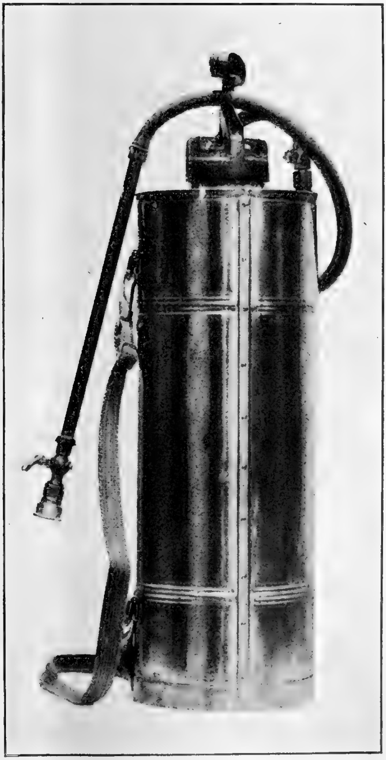

FIG. 6.—Compressed-air sprayer.

row type shown in figure 8, which is a thoroughly effective outfit, capable of giving 120 pounds pressure. It will apply any liquid fungicide or insecticide to vegetables, shrubbery, or orchard trees. The cost is $25. It is often possible to secure the services of a local trucker or orchardist who has a sprayer, but no one should be deterred from protecting his garden when an atomizer may be purchased for 50 cents or even less.

The powders may be shaken from a muslin bag tied to a stick, or various forms of dusters, bellows (fig. 9), or blowers may be bought.

Dry powders are best applied when the leaves are wet with dew.

GENERAL-CROP PESTS.

From the standpoint of their food plants, injurious insects may be grouped roughly into two classes: First, those which are choice feeders and ordinarily attack only a single crop, or crops of a single class, although when they are extremely abundant they may resort to other crops or weeds. Examples are the asparagus beetles and asparagus miner and the large tomato worms, which confine their feeding to plants of a single family. Second, those known as general feeders—insects which are not particular as to their food plants. Some of these devour nearly every form of vegetation that grows in the garden. These include cutworms and other caterpillars, several forms of leaf-beetles and flea-beetles, plant-lice, thrips, blister beetles, and others. When abundant, some of these pests do great damage, sweeping over large areas and ruining entire crops before they can be stopped.

CUTWORMS.

Tomatoes, sweet potatoes, and other truck plants, particularly when started under glass, are likely to be injured by cutworms (fig. 10) when transplanted. These appear in great numbers in the spring and early

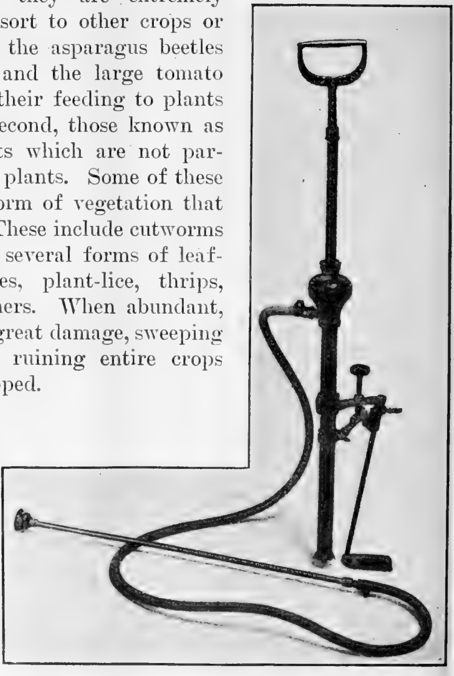

FIG. 7.—A bucket sprayer.

FIG. 8.—A barrow type of sprayer in use.

summer, and the injury is often complete before the gardener notices it. The chief injury is due to the severing of the stems of young plants at about the surface of the ground. One cutworm can destroy many plants in a single night by cutting off more than it can devour.

Control.—The best remedy is what is called "poisoned bait." For use in a small garden take 1 peck of dry bran, add 4 ounces of white arsenic or Paris green, and mix thoroughly with 2 gallons of water in which has been stirred half a gallon of sorghum or other cheap molasses.

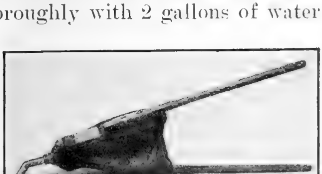

FIG. 9.—A powder bellows.

For a large garden, use 1 bushel of bran to 1 pound of the arsenical mixed with 8 gallons of water containing half a gallon of molasses. This is enough for treating 4 or 5 acres of cultivated crops.

After the mash has stood for several hours, scatter it in lumps the size of a marble over the garden where the injury is beginning to appear and about the bases of the plants set out. Apply late in the day so as to place the poison about the plants before night, which is the time when cutworms are active. Apply a second or third time if necessary.

Arsenic and Paris green are deadly poisons. Handle them with great care.

It is advisable to keep young children, live stock, and chickens away from this bait.

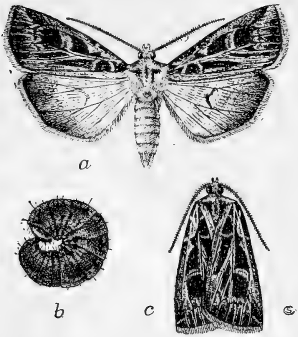

FIG. 10.—The dingy cutworm (*Feltia subgothica*): *a*, Moth, or adult, with wings expanded; *b*, larva, or worm, in curled-up position when feigning death; *c*, moth with wings folded. Somewhat enlarged.

In severe attacks by cutworms on low-growing plants, such as parsley, a lead-arsenate spray will answer in place of the bait.

Clean cultural methods and crop rotation are advisable, as are also deep fall plowing and disking, to prevent recurrences of cutworm attacks. Experienced growers become expert in detecting cutworms and remove them by hand. This often can be done with profit on small patches.

WHITE GRUBS.

When new land is used for planting vegetables, especially land that has been in sod or grown up with weeds, white grubs are almost certain to make their appearance, sometimes in large numbers, doing great damage to plants from the time they attain any growth until the fruit is ready for harvest. They feed chiefly on roots and attack especially potatoes, corn, and strawberries, but they are general feeders. White grubs, or "grub worms," are the larvæ or young of the brown May or June beetles, with which most persons are familiar. (Fig. 11.) The beetles occur in the North as late as August, while in the South they appear in April or earlier.

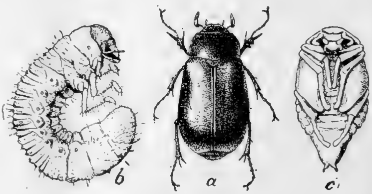

FIG. 11.—A white grub, or May beetle (*Lachnosterna arcuata*): *a*, Beetle; *b*, larva, or grub; *c*, pupa. Enlarged one-fourth.

Control.—Deep plowing is the most effective remedy for white grubs. Cross plowing and deep disking are sometimes necessary, and the ground should be disturbed often and kept clean of weeds so that the grubs can be eliminated.

Rotation of crops, avoiding the planting of potatoes, beets, sweet corn, and other crops on land which has been for some time in the same crops or in strawberries, grasses, or weeds is advisable. Fertilizers, especially kainit, as a heavy top-dressing are of benefit. Gas lime is valuable. (See p. 10.) Hogs, if allowed the run of the newly plowed garden, or when the crop is off, will eat large numbers of grubs. Domestic fowls will pick up grubs on newly plowed land. See Farmers' Bulletin 543, "Common White Grubs."

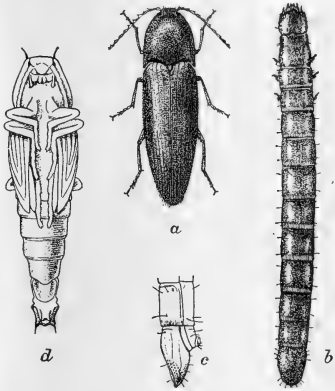

FIG. 12.—The common wireworm (*Melanotus communis*): *a*, Adult; *b*, larva; *c*, last segments of same; *d*, pupa. All enlarged.

WIREWORMS.

Wireworms, like white grubs, are common pests in the garden and are also general feeders. They are the offspring of snapping beetles, or "snap-bugs," and are of long oval form. (Fig. 12.) Their tastes are similar to those of the white grubs. They attack and often do great injury to potatoes and other plants bearing tubers, as well as to carrots, beets, sweet potatoes, and onions.

Control.—The remedies advised for white grubs apply also to wireworms, with due care in selecting land for planting and in fall plowing and crop rotation. Wireworms, however, are much more difficult to control than white grubs.

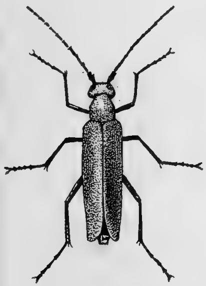

FIG. 13.—The ash-gray blister beetle (*Macrobasis unicolor*): Female beetle. Much enlarged.

BLISTER BEETLES.

Blister beetles (fig. 13) are common farm pests and are very destructive to vegetables, especially beans, peas, potatoes, and beets. They travel in the same manner as army worms and are sometimes called "army beetles" for this reason. They are hungry feeders and travel frequently in lines, eating everything in their path, chewing up apparently more than they need for food. They are slender in form, somewhat soft bodied, and colored variously. Some species are perfectly black, some are yellow with black stripes, others are of the same color with several light stripes, some are gray, and others are gray spotted with black. Blister beetles are particularly abundant in the Southwest, but occur practically everywhere. Different species appear at different times, usually after the plants have made about one-third growth, and they continue until late in the season.

Control.—Lead arsenate applied at the very outset of attack is the best remedy. In some portions of the Southwest lines of men and boys go through fields driving beetles before them until they reach windrows of hay, straw, or other dry vegetable matter previously prepared along the leeward side of the field. The windrow is then fired and the beetles burned. Hand picking is somewhat dangerous, as the blister beetles are likely to form blisters on a delicate skin. It is, moreover, somewhat difficult to collect the beetles, as they are extremely active compared to the sluggish Colorado potato beetle.

GRASSHOPPERS.

Grasshoppers, while more important pests in fields of grain and forage, are often troublesome to vegetables in the dry regions of the Middle West.

Control.—Poisoned baits especially adapted to grasshoppers are generally used, of which the best formula is as follows:

Bran pounds	25
White arsenic or Paris green pound	1
Oranges or lemons fruits	6
Cheap sirup or molasses quarts	2
Water gallons	3 or 4

This should be scattered thinly over infested ground or on plants attacked.

Where it is possible to turn turkeys into gardens without injury to the plants, they will make short work of the grasshoppers. When the fields are plowed, disked, or harrowed, this also destroys the grasshopper eggs. See Farmers' Bulletin 691, "Grasshoppers and Their Control on Sugar Beets and Truck Crops."

PLANT-LICE.

Practically all vegetables, especially cucumbers, cabbages, and peas, suffer considerable damage from attack by small, soft-bodied insects commonly called "lice" or "aphis," but better known as plant-lice. (See fig. 39, p. 35, and fig. 50, p. 45.) These work for the most part on the lower sides of the leaves, which become curled or otherwise destroyed by loss of their vital juices. They give off a sweet mixture called honeydew, which attracts ants, flies, and other insects. Plant-lice increase with great rapidity by the female giving birth to living young. The different kinds vary in color from light to dark green or nearly black, grayish, brown, yellow, and red. They have comparatively long legs and have feelers attached to the head. Some forms have two pairs of transparent or clear wings. They feed by sucking juices of the plants through a beak. Familiar examples are the melon aphis, pea aphis, and cabbage plant-lice.

Control.—If the plants are grown under glass, plant-lice may be killed by fumigation with a nicotine preparation. The form suitable for this work is paper soaked in nicotine which when lighted causes a smudge. Sprinkling plants with fine tobacco dust is of some value, especially if applied early in the morning when the dew is on. Under large vegetable garden conditions standard 40 per cent nicotine sulphate gives almost perfect results if properly diluted and applied. It may be used at the rate of 1 teaspoonful of sulphate to 1 gallon of water with a 1-inch cube of laundry soap. See "Nicotine sulphate" (p. 10).

ANTS.

Certain species of ants may be found afield from March to October, and often occur in greenhouses and coldframes attacking cabbage and related plants, eggplant, lettuce, beans, parsley, radishes, tomatoes, and peppers. They attack the roots, crown, and lower portions of the stem, and completely destroy young plants.

Control.—The best remedy is fumigating the nests with carbon disulphid by means of a machine oil can made of metal. Locate the nest and, if possible, the female, or queen. Inject about two or three teaspoonfuls of the liquid into the entrance to the nest, and if not effective soon repeat the dose a little stronger. Hot water will answer the purpose if the insects are not too abundant. Poisoned baits as for cutworms have been used with good effect. See "Cutworms" (p. 14). Careful watch should be kept for the appearance of these insects in lawns and elsewhere about the grounds and the nests destroyed. Consult Farmers' Bulletin 740 on "House Ants."

ONION THRIPS.

The onion thrips (fig. 14), incorrectly called "thrip," is microscopic in size and is often called the onion louse. It causes an injury somewhat generally known as white blast, white blight, and silver top. It also causes scullions, or thick necks—poorly developed and unmarketable bulbs. This species frequently ruins entire fields of onions. Besides the truck crops mentioned this thrips attacks cauliflower, cabbages, cucumbers, melons, pumpkins, squashes, parsley, tomatoes, kale, turnips, and seed beets. It is what is known as a general feeder, and it would be easier to mention plants which it does not attack than to list those which it uses as food.

Control.—Nicotine sulphate, as advised on pages 10 and 11, is used with success.

TARNISHED PLANT-BUG.

Nearly all vegetables are attacked by the tarnished plant-bug (fig. 15), a small leaf-bug measuring about one-fifth of an inch in length when mature. There are five distinct stages, called "nymphs," from the time the egg is laid until the adult or winged form appears. This species is injurious to cabbages, turnips, potatoes, and cucumbers, and injury generally is done by the adults piercing and sucking the

FIG. 14.—The onion thrips (*Thrips tabaci*): Adult. Highly magnified.

juices from the plants and later attacking fruits and shoots. It is the cause of "buttoning," and is credited with carrying some forms of blight on plants. Were it not that this insect feeds on so great a variety of plants, thus distributing its attack, it would be a serious pest indeed.

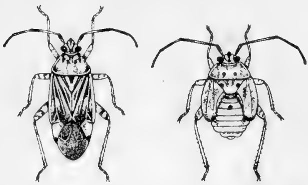

FIG. 15.—The tarnished plant-bug (*Lygus pratensis*): Adult bug at left; last stage of nymph at right. Nearly four times natural size.

Control.—This plant-bug, when it occurs in great numbers, can not be kept within bounds by any single remedy. The great activity of the pest makes it particularly difficult to control. The best remedies are nicotine sulphate, kerosene-soap emulsion, and fish-oil soap. As in the case of plant-lice, insecticides must be applied in the morning before the insects have become thoroughly active and while dew is on the plants. In the small garden, sweeping all the plants, grasses, and weeds with an insect-collecting net will accomplish much toward keeping the pest in subjection.

RED SPIDER.

Practically all vegetables are subject to attack by the red spider (fig. 16). It is not a true spider but a mite, the latter name being indicative of its minute size. It is well distributed throughout the country. Among vegetables and truck crops most attacked are beans of all kinds, cowpeas, eggplant, cucumbers, tomatoes, melons, squashes, strawberries, raspberries, beets, and celery. It is also a greenhouse pest and does great damage to cucumbers and tomatoes, as well as to ornamental plants grown under glass. It is a general feeder in the broadest sense, infesting the foliage of shade and fruit trees and some field crops. It is often present on the under surface of leaves like beans without being suspected. This mite injures plants by sucking the juices, and when plants are neglected their vitality is slowly reduced by loss of sap, and in time all of the plant's functions are deranged. In case of severe attack, millions of red spiders can be found on the foliage, and the webs which the insect spins from plant to plant can be easily seen, with the mites themselves passing rapidly over them and congregating in swarms. Sometimes the plants look as though stricken by fire.

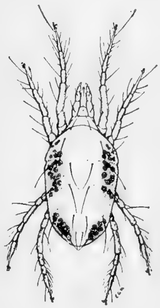

FIG. 16.—The female red spider (*Tetranychus telarius*). Highly magnified. (McGregor and McDonough.)

Control.—The remedies are spraying with soap solutions, kerosene-soap emulsion, and sulphur preparations. Flowers of sulphur mixed with water at the rate of 1 ounce to 1 gallon sprayed over infested plants is of great benefit. Unless remedial measures are adopted early and applied as often as necessity demands, red spiders are almost certain to do great harm to delicate plants, since if the plants become thoroughly infested they seldom survive. Frequent spraying with soap and water will often keep the pests in check, especially in greenhouses.

SLUGS AND SNAILS.

FIG. 17.—The imported garden slug (*Limax maximus*).

Much harm is done by slugs (fig. 17), little animals sometimes classified as insects, but really mollusks. They are not provided with shells, while snails are shell bearers. The latter are also sometimes troublesome, but their injury is limited. Attack is most severe on delicate seedlings grown in hotbeds, and in coldframes. Delicate garden vegetables of nearly all kinds also are injured by them in the open, attack beginning when the plants are near the ground and even after the crop is ripening. Potatoes are bored into, and celery is often badly injured during the bleaching process.

Control.—The best remedy is a preventive and consists of lime in any form, quicklime being the most useful, sprinkled over the plants and scattered about the haunts of the slugs, which means all about the garden, buildings, outhouses, and fences. When the lime comes into contact with the slug, the latter secretes slime copiously and in time this completely exhausts the animal and it dies.

Other remedies are soot, dust, sifted wood ashes, and kainit. By scattering a line of any of these substances around a garden, cold-frame, or other inclosure, it will serve to keep the slugs away. To avoid slugs it is desirable to remove all rotten wood and old structures, and to keep the entire garden and yard free from rubbish of all kinds.

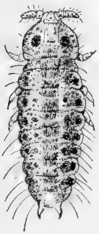

FIG. 18.—A common injurious springtail (*Achorutes armatum*). Much enlarged. (Popenoe.)

SPRINGTAILS.

Springtails (fig. 18) are minute, dark-colored, soft-bodied insects which hop like fleas. They have the same habit as flea-beetles of pitting the first-appearing leaves of all kinds of seedlings, which causes much disfigurement and reduces the yield of the crop.

Control.—The control is the same as for flea-beetles—Bordeaux mixture combined with lead arsenate or Paris green.

GENERAL-CROP DISEASES.

While most plant diseases attack only one crop or a group of related plants, there are some troubles which may occur on almost any of the garden vegetables, as a rule on the underground parts. These are Rhizoctonia, root-knot, and damping-off.

RHIZOCTONIA.

We might find a shorter name for this fungus, but more people know it and its effects by this term than as stem-blight, root-rot, scurf, or rosette. Among the plants attacked are potatoes, beets, beans, celery, lettuce, and carnations.

Dark cankers or dead spots are produced on the stem or roots (fig. 19), which may decay and weaken or kill the plant.

It is difficult to prevent or to control. Keep the soil in good tilth and the plants under the most favorable growing conditions possible.

ROOT-KNOT.

Southern gardens suffer greatly from the eelworm, gallworm, or nematode, which causes irregular swellings or galls on the roots of nearly all vegetables. (See fig. 2, p. 5.) It is most troublesome in sandy soils. Do not confuse this with the beneficial nodules on beans and other legumes or with the clubroot of the cabbage family.

A garden infested with root-knot may produce winter crops, as the eelworms are inactive in cold weather, but for summer crops a new location must be chosen. See Farmers' Bulletin 648.

FIG. 19.—Rhizoctonia on potato, causing dark, dead areas on the underground parts.

DAMPING-OFF.

Home gardeners who plant seed early in frames or in boxes in the house frequently lose the young plants shortly after they have germinated. The seedlings shrivel or decay at the soil line, collapse, and fall over. This is damping-off and is due to a fungus in the soil which attacks little plants that have been overwatered or kept too warm.

To prevent damping-off give light and ventilation, but avoid cold drafts. Water in the morning, so the soil will dry before night. Where a spot of damping-off has appeared, take out the affected plants, give more light and air, and sprinkle warm sand on the surface.

Sterilizing the soil of seed boxes will help to avoid the trouble. This can be done with small quantities by heating thoroughly in an oven soil which is moist, yet dry enough to crumble in the fingers.

The pressure cookers or steam sterilizers used for canning purposes are excellent for sterilizing soil.

PRINCIPAL GARDEN CROPS AND THE INSECTS AND DISEASES THAT ATTACK THEM.

ASPARAGUS.

ASPARAGUS BEETLES.

Two small beetles, one blue-black with yellow and dark-blue wing covers, the other red with black spots on the wing covers, the former known as the common, or blue, asparagus beetle (figs. 20–21), and the latter as the 12-spotted,[1] or red, asparagus beetle, do much injury to asparagus over the eastern United States. Attack begins with the first-appearing tips and continues until cold weather. The former eats the foliage both as a beetle and as a larva, or "slug." The latter's attack is confined to the beetle, the slug feeding inside the growing berry.

FIG. 20.—Spray of asparagus, with common, or blue, asparagus beetle (*Crioceris asparagi*) in its different stages; asparagus tip at right, showing eggs and injury. Somewhat reduced.

Control.—The best remedy is lead arsenate, sprayed, as for the Colorado potato beetle, from both sides of a plant, as the beetles are active and the foliage is difficult to reach, so as to leave a coating of poison. The tips for market should be cut as early and as promptly as possible in order to prevent injury. Dust the plants of larger growth, including volunteer plants, with fresh air-slaked lime while the dew is on. This destroys all slugs when it comes in contact with them. The slugs also may be killed in hot weather by brushing them from the plants with a switch so that they drop to the bare ground. They are delicate and crawl slowly, so that few are able to return to the plants, most of them dying from exposure to the heated earth. Since the red species develops in the berry, the slugs can not be reached by a spray. Collect the berries and promptly destroy them with the contained slugs. Consult Farmers' Bulletin 837.

ASPARAGUS MINER.

The maggot of a minute black fly, the asparagus miner, also does considerable injury, but it is not so well known as the beetles because of its small size.

[1] *Crioceris duodecimpunctata* L.

Control.—It may be controlled to a considerable extent by using nicotine sulphate. The last generation can be killed by pulling and

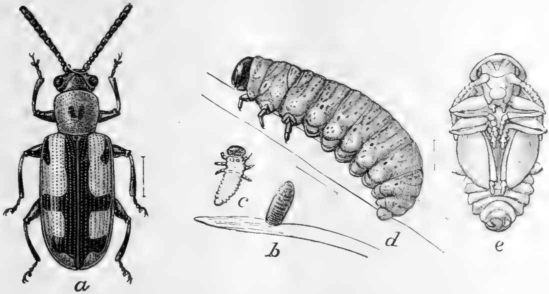

FIG. 21.—Common asparagus beetle: *a*, Beetle; *b*, egg; *c*, newly hatched larva; *d*, full-grown larva; *e*, pupa. Much enlarged.

promptly burning old infested stalks as soon as attack is noticed. Late in the fall, instead of cutting off the tops, as is the usual custom, pull them and burn them promptly. The rust-resistant plants mentioned below are also somewhat resistant to the miner.

FIG. 22.—Asparagus rust.

ASPARAGUS RUST.

To control asparagus rust (fig. 22), plant the resistant varieties Reading Giant, Argenteuil, or Palmetto. Spraying with Bordeaux mixture is not recommended.

BEANS.

ANTHRACNOSE.

Bean anthracnose is caused by a fungus which attacks the stems, leaves, pods, and seeds of the plants. On the stems and leaf veins it causes elongated, sunken, dark-red cankers, sometimes killing young plants and often producing deformed and yellowed leaves. Rounded or irregular sunken spots with a slightly raised rim are produced on the pods. (Fig. 23.) The spots usually have pink centers surrounded by a darker reddish border. In severe case the pods may be entirely covered by the sores and produce no seed. In other cases the fungus penetrates the pods and enters the seed, causing dark, sunken specks or spots. In these diseased seeds as well as in the refuse from diseased plants the fungus is propagated from season to season.

FIG. 23.—Bean anthracnose.

Control.—It has been demonstrated conclusively that anthracnose can be avoided by a careful system of seed selection. Save seed from perfectly healthy pods, selected with great care for entire absence of spotting. Carefully keep them away from diseased pods, shell by hand to avoid reinfection, and plant on clean land. Pull and burn any plants showing disease.

In the absence of such disease-free seed (1) secure for planting seed having the least possible amount of disease, as shown by actual examination; (2) all seed should be hand picked, and no seed showing the slightest discoloration should be planted; (3) practice crop rotation, and never plant beans on land where there is any refuse of last year's crop; (4) do not cultivate or walk through the bean field or pick beans while wet with dew or rain. If the disease is present, it is then easily spread from one part of the field to another.

FIG. 24.—Bean blight on leaf and pod.

BEAN BLIGHT.

Bean blight differs from anthracnose in several ways. It is caused by a bacterial organism. On the leaves it produces irregular, diseased areas which at first have a water-soaked appearance, but later dry out and become brown and brittle. (Fig. 24.) On the pods the disease starts as slightly raised and watery pustules, which later enlarge and become of irregular shape and amber in color. Infected seeds show yellow diseased blotches or are entirely yellowed and shriveled.

The bean blight is more difficult to control than anthracnose, but the same methods will give the best results at present available.

DOWNY MILDEW.

Lima beans are sometimes attacked by downy mildew, which covers the pods with a thick, felty, white growth. (Fig. 25.) If taken in time this disease can be controlled by thorough spraying with Bordeaux mixture. Apply when the disease appears and repeat at 10-day intervals as needed. Burn diseased pods.

FIG. 25.—Downy mildew of Lima bean.

WEEVILS.

The principal insect enemies of beans are several species of bean weevils. The cowpea weevil also attacks beans when cowpeas are not available. Attack begins in the field from eggs deposited in a joint in the pod or opening through which the egg is thrust; the larva, or grub, develops within, and soon after the beans are harvested the weevils begin to develop, according to the temperature. A second generation of the common bean weevil (fig. 26) may be sufficient to destroy a crop of beans for either human consumption or seed. Several generations may be produced in a year.

The bean weevils vary in color. The common bean weevil is dull gray with reddish legs. None of these insects is much more than one-eighth of an inch long, and some are shorter.

Control.—Bean weevils can not be controlled in the field. They breed continuously in dried seed, and it is therefore advisable to harvest the crop and as soon as dry to fumigate with carbon disulphid. See Farmers' Bulletin 799, "Carbon Disulphid as an Insecticide."

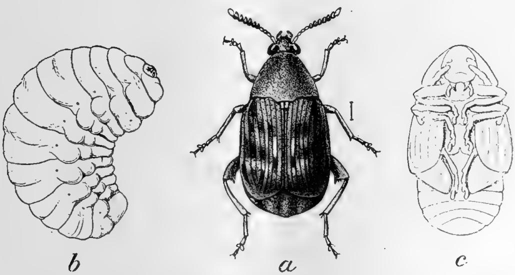

FIG. 26.—The common bean weevil (*Bruchus obtectus*): *a*, Beetle; *b*, larva, or grub; *c*, pupa. Greatly enlarged.

BEAN FLY, OR SEED-CORN MAGGOT.

The seed-corn maggot, also called the bean fly (fig. 57, p. 52), an insect of about the size and appearance of the house fly, does great injury to early-planted beans, peas, and similar crops, and is frequently the cause of the failure of such plants to develop. The maggot scrapes or tunnels the seeds, sprouts, and stems of plants, both under ground and in the stalks above, decay soon sets in, and the plants die. Entire plantings are frequently destroyed.

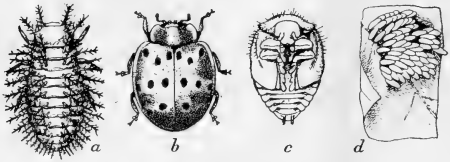

FIG. 27.—The bean ladybird (*Epilachna corrupta*): *a*, Larva; *b*, beetle; *c*, pupa; *d*, egg mass. About three times natural size.

Control.—Much injury can be prevented by using mineral fertilizers, since soil containing much humus or mold or treated with barnyard manure is most subject to attack. Hand picking, although laborious, is effective, and can be used in a small garden. The standard remedy is carbolic-acid emulsion (see p. 8).

BEAN LADYBIRD.

The bean ladybird (fig. 27) is very injurious from Colorado southward to Mexico. It is the worst enemy to the bean crop of that region, and its work is compared to that of the Colorado potato beetle. Both grubs and beetles devour all portions of the plants—leaves, flowers, and green pods.

Control.—Use remedies advised for the Colorado potato beetle (p. 56). A spray strong enough to kill the beetles is apt to injure the foliage. Do not plant beans two years in succession in the same region.

BEAN LEAF-BEETLE.

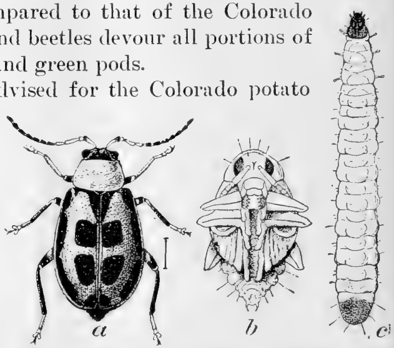

FIG. 28.—The bean leaf-beetle (*Cerotoma trifurcata*): *a*, Adult beetle; *b*, pupa; *c*, larva, or grub. Greatly enlarged.

The bean leaf-beetle (fig. 28) does much injury in the Eastern States and from Ohio southward to Louisiana. The beetles eat large round holes in growing leaves and feed also on related wild plants, such as beggarweed or tickseed. The grubs feed on the roots and main stem just below the surface, their habits being much the same as those of the better known cucumber beetles.

Control.—Lead arsenate is the best remedy for this species. On young beans it must be applied at half strength to avoid burning the plants.

BEAN APHIS.

The bean aphis, a minute blackish plant-louse and a widely distributed pest, does injury throughout the country, being especially troublesome in California, working on the early plants.

Control.—Nicotine sulphate is the best remedy, applied as soon as possible and repeated as found necessary.

BLISTER BEETLES.

Beans and related plants are especially favored by blister beetles, and it is a common sight to see different forms travel from beets to beans or potatoes. See "Blister beetles" (p. 17).

BEETS.

BEET FLEA-BEETLE.

The beet flea-beetle (fig. 29), also known as the spinach flea-beetle, is particularly injurious to table beets, attacking them as soon as they are above ground. The young, or larvæ, develop on chickweed and lamb's-quarters, and a second brood is soon produced to attack the beets. The young frequently develop in such numbers as literally to "clean out" entire rows of beets before they are even noticed by the gardener. They even work down and bore into the crown of the plants.

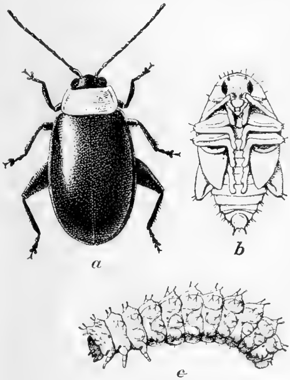

Fig. 29.—The beet, or spinach, flea-beetle (*Disonycha xanthomelaena*): *a*, Beetle; *b*, pupa; *c*, full-grown larva. Five times natural size.

Control.—As this species is rather large for a flea-beetle, it can be controlled readily by arsenate of lead applied on the first appearance of the pest and renewed as often as needed. Since chickweed and lamb's-quarters are the natural food plants, they should be kept down in the early spring, not only on account of this insect but because of cutworms which develop on the same plants.

BLISTER BEETLES.

Blister beetles are almost as injurious to beets as to potatoes and devour the plants in the same way. For control, see "Blister beetles" (p. 17).

BEET ARMY WORM.

The beet army worm (fig. 30) is more injurious to beets than to other plants; hence the name. When numerous it is found also on potatoes, peas, onions, and other vegetables and grasses. It is a western form and capable of doing much damage.

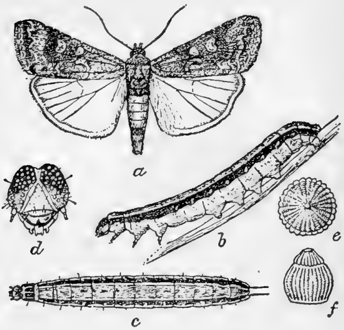

FIG. 30.—The beet army worm (*Caradrina exigua*): *a*, Moth; *b*, larva, side view; *c*, larva, dorsal view; *d*, head of larva; *e*, egg, viewed from above; *f*, egg, from side. All enlarged.

Control.—When occurring in moderate numbers this insect can be held in control by lead arsenate; when unusually abundant, remedies used for the true army worm are necessary. (See Farmers' Bulletin 835, pp. 9–11.)

BEET WEBWORM.

Several forms of webworms attack beets by eating the leaves, which become webbed together in the growing plants. The most injurious species is illustrated in figures 31 and 32.

Control.—Arsenate of lead spray. Gardens should be kept free from such weeds as pigweed and lamb's-quarters, since these encourage webworms and permit their spread.

FIG. 31.—The sugar-beet webworm (*Loxostege sticticalis*): Moth. Twice natural size (Howard and Riley).

FIG. 32.—The sugar-beet webworm (*Loxostege sticticalis*): Full-grown larva. Enlarged.

WHITE GRUBS AND WIREWORMS.

White grubs and wireworms do considerable damage to beets, especially if beets are grown in prairie and alkali land. For control, see "White grubs" and "Wireworms" (pp. 16 and 17).

LEAF-SPOT.

In leaf-spot, circular, brown, dead spots appear on the leaves (fig. 33). Spray with Bordeaux mixture when the first spots appear and repeat at 10-day intervals.

CABBAGE.

COMMON CABBAGE WORM.

The common cabbage worm (fig. 34) is known to most farmers, and the butterfly is also a familiar object; but in some cases the growers do not associate the velvety green caterpillar with the parent white butterfly. This cabbage worm has been termed rightly the bane of the cabbage grower and the dread of every careful cook and housewife. It begins work early in the season, attacking the first young plants which it can find (fig. 35). After riddling the outer leaves, which remain afterward attached to the stalk, the worm attacks the tender inner leaves as they form, hiding in the immature heads, where it is difficult to reach it with a spray and rendering the cabbage heads unfit for food, partly owing to the filthy condition in which it leaves them. For this reason cabbage heads before being marketed must be examined with care and damaged leaves removed. They also should be washed thoroughly.

FIG. 33.—Beet leaf-spot.

In cool weather the caterpillars often feed freely exposed on the upper surface of the leaves in the sunshine, and at such times they are easy to combat. The cabbage worm does hardly less damage to cauliflower, kale, collards, turnips, radishes, and horse-radish. The butterflies occur even in the more northern States from March to October, and the worms are at work in the same region from April to September and occasionally later during warm winters.

Control.—Arsenate of lead is the best remedy, and while it leaves a coating on the outer leaves until late in the season, it remains to be seen whether this affects even domestic animals. These leaves always are removed before cooking, and whatever trace of arsenate might remain would not be injurious to the consumer. See Farmers' Bulletin 766.

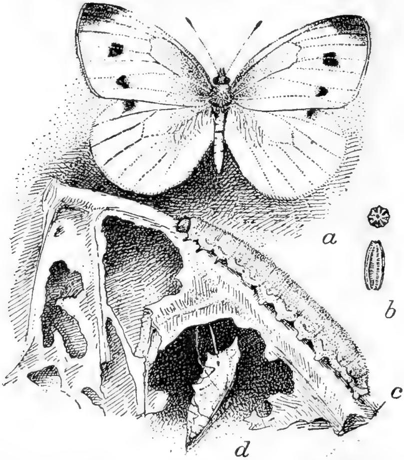

FIG. 34.—The common cabbage worm (*Pontia rapae*): *a*, Female butterfly; *b*, egg (above as seen from above, below as seen from side); *c*, larva, or worm, in natural position on cabbage leaf; *d*, suspended chrysalis. *a*, *c*, *d*, Slightly enlarged; *b*, more enlarged.

OTHER CABBAGE WORMS.

Other species of butterflies as well as moths produce what are commonly called caterpillars, and these can not be readily identified by the average grower until full grown, since in their early stages they resemble one another. Of these there is the southern cabbage butterfly,[1] which resembles the common cabbage worm in the adult stage, being, however,

FIG. 35.—Cabbage seedlings grown in coldframes, showing injury by the common cabbage worm. This necessitates replanting and additional labor, and causes delay in getting cabbages to the early market.

[1] *Pontia protodice* Boisd.

perfectly white, while the worm is more strongly colored, purplish, and yellow striped, with black spots bearing black hairs. Another is the potherb butterfly,[1] a species practically confined to the North as a pest. The worm is uniform pale green and resembles closely the cabbage leaves on which it feeds. The cross-striped cabbage worm (fig. 36) is the young of a moth. It has the very bad habit of the common cabbage worm of boring into the head, and it is very difficult to dislodge.

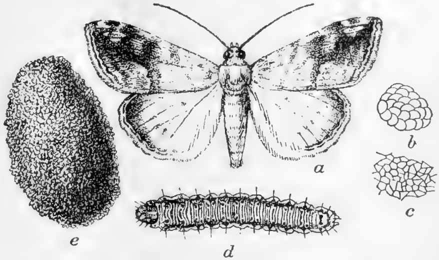

FIG. 36.—The cross-striped cabbage worm (*Evergestis rimosalis*): *a*, Moth; *b*, egg mass; *c*, portion of egg, highly magnified; *d*, larva, or worm; *e*, cocoon. Much enlarged.

Control.—The remedies advised as the best for the control of the common cabbage worm are valuable for all of these species.

CABBAGE LOOPER.

The cabbage looper (fig. 37) is the young, or worm, of a medium-sized moth resembling a cutworm moth. It is pale green and delicate looking when first hatched. When larger, it becomes striped and obtains its name of looper through its habit of doubling up, or looping, as it walks. It is more active than the other cabbage worms previously considered and is, therefore, more difficult to control. It affects all forms of cole crops, and at times does great injury to peas, beets, celery, and lettuce, even attacking the tomato and potato. It is apparently three-brooded from the District of Columbia northward to Long Island and is more destructive southward.


FIG. 37.—The cabbage looper (*Autographa brassicae*): Above, male moth; below, full-grown larva in natural position feeding, and pupa in cocoon just before development of moth. Moth and larva about one-third larger than natural size; pupa more enlarged.

Control.—Spraying with arsenate of lead is the best remedy. An adhesive, or "sticker,"

[1] *Pontia napi* L.

should be used when applied to cabbage, cauliflower, and similar smooth-leafed plants; otherwise the spray is not likely to adhere so well. In the kitchen garden hand picking is sometimes practiced. Clean farming is also desirable, and the clearing up and burning of all cruciferous weeds before planting. It is equally desirable in the case of this and other cabbage pests to destroy all injured plants and stalks by burning as soon as the main crop is harvested.

HARLEQUIN CABBAGE BUG.

The harlequin cabbage bug (fig. 38) is known also as the calico bug, fire bug, and terrapin bug. In the South this species is more

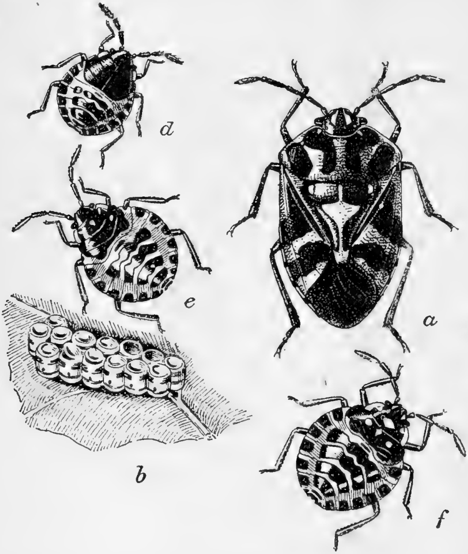

FIG. 38.—Harlequin cabbage bug (*Murgantia histrionica*): *a*, Adult; *b*, egg mass; *c*, first stage of nymph; *d*, second stage; *e*, third stage; *f*, fourth stage; *g*, fifth stage. Enlarged.

injurious than the common cabbage worm and, indeed, is classified as one of the most important pests of the country. The name "harlequin bug" aptly describes this species. It is gay red, ornamented like the harlequin of the stage. Normally it occurs from southern Virginia to California, but prefers the warmer States.

Control.—Of the direct methods of control nicotine sulphate is advised (see p. 10). Kerosene emulsion and fish-oil soap are less effective unless used strong. The newly hatched young are much more easily killed than the harder and hardier adults. The plumber's torch is effective for this pest, destroying all the insects with which the flame comes in contact, after which the plants revive and grow well. The torch is more safely applied to the late fall crop. It is apt to injure the earlier, spring crop. These torches are not practical against many other insects, and their use should be restricted to this species and a few others. Other remedies are (1) clean culture, especially in the fall, (2) trap crops of mustard or other crops in the spring, and (3) hand picking of adults and eggs early in the season. The systematic destruction of this insect by means of a trap-crop method, i. e., planting early cole crops to attract the insects before the main crop is on and then destroying the insects by burning them, with the other methods advised, will help materially to keep this pest from doing much damage. Especially it is advisable to kill off the first and the last broods and to try to prevent the insect from gaining a foothold in the North.

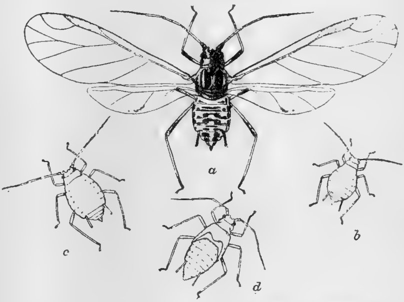

FIG. 39.—The spinach aphis (*Myzus persicae*): *a*, Winged adult aphis; *b*, young nymph; *c*, older nymph; *d*, last stage of nymph, or pupa. Greatly enlarged.

PLANT-LICE.

Plant-lice of three species, known commonly as the cabbage aphis, turnip aphis, and spinach aphis (fig. 39), do much damage to cabbage in some seasons, but fortunately, although generally distributed, they are not injurious in all years in all localities. These insects so closely resemble one another that a description hardly would appeal to the grower who maintains a vegetable garden as a side issue. They appear early in the spring and sometimes remain as late as December.

Control.—The best remedy is nicotine sulphate (see p. 10). Kerosene emulsion and soaps, especially fish-oil soap, also are valuable, and a strong stream of water frequently directed upon the plants from a syringe, garden hose, or sprayer is often of service in checking these pests. The early application of remedies is advisable. Clean culture, as for the harlequin cabbage bug and other insects affecting cole crops, should also be practiced.

FLEA-BEETLES.

Several forms of flea-beetles attack young cole crops, generally preferring cabbage, some of them being striped and others plain greenish or bluish in color. They are a little larger than fleas and have the same jumping habits. Nevertheless they can be controlled by lead arsenate employed as for cabbage worms. Bordeaux mixture with resin fish-oil soap is an excellent deterrent. (See p. 7.)

THE CABBAGE MAGGOT.[1]

Cabbage and related crops frequently suffer severe injury from the attack of the cabbage maggot, an insect closely related to the seed-corn maggot (fig. 57, p. 52) and very similar in appearance. Young plants are the ones most seriously affected, the maggots eroding the outer surface and boring into the interior of the roots, devouring the tender rootlets and frequently penetrating into the lower portion of the stalk. This maggot does the most serious injury throughout the northern tier of States and Canada, attacking all forms of crucifers, whether wild or cultivated. In that region it is the cause of loss to crops year after year, but, as with other destructive insects, it is much more abundant in some seasons than in others. When it occurs in abundance it is one of the most difficult pests to control unless use is made of tarred paper pads and other methods to be described.

Control.—The remedies prescribed for the seed-corn maggot (see p. 28) are sometimes applicable. In addition there are certain preventives and measures for its destruction that have been found successful, their use being justified by the great value of cabbage plants.

Carbolic-acid emulsion, prepared as advised (p. 8) is particularly applicable when this maggot occurs on radish and plants other than cabbage and cauliflower.

Hand picking, although laborious, has the merit of being effective, and is practiced with considerable success by those growing cabbage on an extensive scale, although not practicable on radish, turnip, and similar crops. It consists in pulling up the young cabbage or cauliflower plants, examining the roots for eggs and maggots, and destroying the eggs and maggots by crushing them with the hand or by washing the roots in a strong solution of soap, and then replanting. In most cases the plants show no ill effects from this treatment after two or three weeks have elapsed. On close examination the minute white eggs may be seen about the stalks of young cabbages; and if the earth be raked away so as to expose the eggs to the sun, these will dry up, thus preventing the maggots from hatching. Afterwards the plants should be hilled.

Although little is to be expected from certain farming methods which are sometimes perfect safeguards against other insects, the following measures are helpful. Keeping the soil well hilled around the plants promotes root development, thus lessening the likelihood

[1] *Pegomya brassicae* Bouché.

that the plants will succumb to any ordinary attack. A rotation should be practiced in which cabbage, cauliflower, etc., are followed by plants other than cole crops. Fall plowing is advisable. Crop remnants, and particularly cabbage stumps, should be removed and destroyed, especially early in the season, since this protects other cole crops against other pests which are harbored in the old stalks or feed on the new leaves in early winter, to reappear the next spring.

The use of disks or pads of tarred paper for the protection of cabbage against the oviposition of the fly was perfected in 1889 as follows:

> The cards are cut in a hexagonal form (fig. 40, *c*) in order better to economize the material, and a thinner grade of tarred paper than the ordinary roofing felt is used, as it is not only cheaper, but, being more flexible, the cards made from it are more readily placed about the plants without being torn.
>
> The blade of the tool, which should be made by an expert blacksmith, is formed from a band of steel, which is bent in the form of a half hexagon, and then, taking an acute angle reaches nearly to the center, as shown in figure 40, *a*. The part making the star-shaped cut is formed from a separate piece of steel, so attached to the handle as to make a close joint with the blade. The latter is beveled from the outside all around, so that by removing the part making the star-shaped cut the edge may be ground on a grindstone. It is important that the angles in the blade be made perfect, and that its outline represent an exact half hexagon.

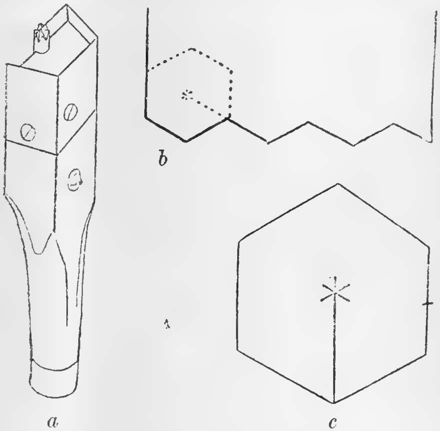

FIG. 40.—*a*, Tool for cutting tarred paper pads; *b*, diagram showing how tool is used, the dotted line showing position of edge of tool; *c*, tarred paper pad in outline. *a*, *b*, One-fourth natural size; *c*, one-half natural size.

> To use the tool, place the tarred paper on the end of a section of a log or piece of timber and first cut the lower edge into notches, as indicated in figure 40, *b*, using only one angle of the tool. Then commence at the left side and place the blade as indicated by the dotted lines, and strike at the end of the handle with a light mallet, and a complete card is made. Continue in this manner across the paper. The first cut of every alternate course will make an imperfect card, and the last cut in any course may be imperfect, but the other cuts will make perfect cards if the tool is correctly made and properly used.
>
> The cards should be placed about the plants at the time of transplanting. To place the card, bend it slightly, to open the slit, then slip it on the center,

the stem entering the slit, after which spread the card out flat and press the points formed by the star-shaped cut snugly around the stem.

A Wisconsin grower protected 7,000 plants and secured a splendid crop, while unprotected plants near by would have been a complete failure if the maggots had not been picked off by hand. Others have reported similar success. One reported having lost only 25 plants out of 10,000 to 15,000 that he protected with the cards, where ordinarily he would have lost from 75 to 90 per cent of the crop. Some growers in Wisconsin have used this method with almost perfect success for upwards of 20 years. The tarred pads are applicable to cabbage and cauliflower only, but they are cheaper, more practicable, and more efficient than anything else yet devised for preventing the ravages of the cabbage maggot. Success in using them is dependent upon their being properly applied, *to fit tightly*, so that the fly will be unable to obtain access to the stem to lay her eggs. Pads must be renewed and their use continued every year, to be effective.

FIG. 41.—Cabbage black-leg.

BLACK-LEG.

In black-leg the plants show a purple color and the leaves wilt, but remain adhering to the stem. Sunken, diseased spots occur on leaves and stem, in which numerous tiny black specks may be seen. The stem is often girdled. (Fig. 41.)

Preventive measures.—(1) Disinfect seed with corrosive sublimate, 1 tablet to a pint of water for 10 minutes; (2) use disease-free soil for the seed bed; (3) avoid contaminated manure; (4) in setting plants use no contaminated water; (5) practice a long crop rotation.

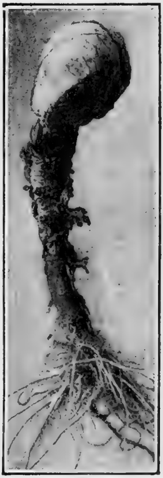

FIG. 42.—Cabbage yellows.

YELLOWS.

The leaves of cabbage often yellow and fall off, the lower ones first, leaving a bare stem and small, imperfect head. (Fig. 42.) The inner wood of the stem is blackened. The yellowing of the leaves and of the plant is often one-sided. This disease is caused by a soil fungus.

Control.—Resistant varieties are being bred. Until these are available, practice the same treatment as for black-leg.

BLACK-ROT.

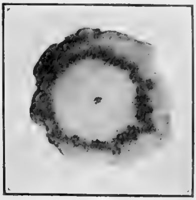

Fig. 43.—Cabbage black-rot. Cross section of stem of diseased plant, showing blackened ring.

In black-rot, dead brown areas appear on the leaf margins. The disease progresses downward through the veins, which are blackened. The inner wood of the stem is dark. (Fig. 43.) The heads are dwarfed or one-sided, and later may decay and fall off.

Control is difficult. Use the same preventive measures as for black-leg. Keep insects, slugs, snails, etc., in subjection, as they may spread the disease. Pull or destroy diseased plants.

CLUBROOT.

The plants may be attacked by clubroot in the seed bed or later. They are stunted, sickly, and wilt during the heat of the day. The roots become greatly swollen and malformed. (Fig. 3, p. 6.) This disease also attacks turnips, cauliflower, mustard, and other cultivated and wild plants of the cabbage family.

Fig. 44.—Celery leaf-blight.

Control.—Apply lime, preferably air slaked, at the rate of 40 pounds per square rod, working it deep into the soil several months before planting. Take special care that the seedlings are healthy. Destroy diseased plants.

SOFT-ROT.

The heads go down rapidly in the field, especially in warm weather, with a soft rot. Harvest early and avoid replanting the same spot.

CELERY.

LEAF-BLIGHT.

Leaf-blight is a spotting of the leaves (fig. 44). There are two forms, the early and the late, due to different fungi, but controlled by the same means. Spray the celery in the seed bed with Bordeaux mixture and repeat every 10 to 14 days until the celery is mature.

A comparatively small number of injurious insects affect celery, with the exception of general feeders. Those which prefer celery usually live also on the related plants, carrots, parsley, and parsnips. For convenience, pests of these plants may be considered together.

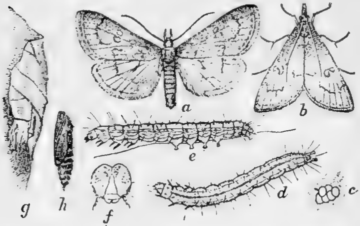

FIG. 45.—The celery leaf-tyer (*Phlyctaenia ferrugalis*): *a*, Moth; *b*, same in natural position at rest; *c*, egg mass; *d*, larva from above; *e*, same from side; *f*, head of same; *g*, pupa case; *h*, chrysalis. *a*, *b*, *d*, *e*, *g*, *h*, one-half larger than natural size; *c*, twice natural size; *f*, more enlarged.

CELERY LEAF-TYER.

The celery leaf-tyer (fig. 45) is known also as the greenhouse leaf-tyer. While more abundant in greenhouses, attacking various plants, such as the roses, violets, and carnations, it is injurious to garden celery, cabbages, beets, lettuce, cauliflower, parsley, and cucumbers. The moth has a wing expanse of about three-fourths of an inch and is clay-brown, ornamented with black lines. The larva, or caterpillar, is green or greenish yellow, nearly transparent, with darker head, and striped. The leaf-tyer usually works on the under side of leaves, chiefly at night, resting by day in the same location.

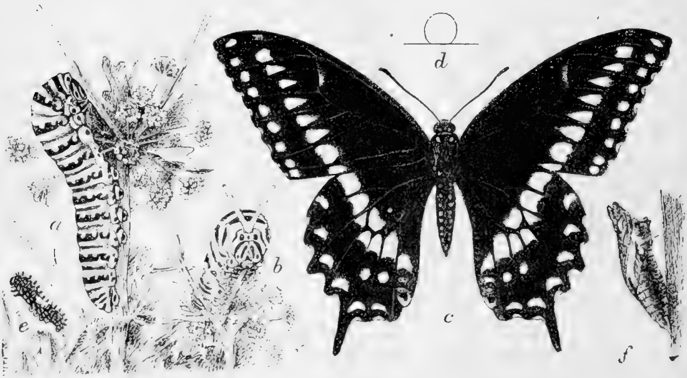

FIG. 46.—The celery caterpillar (*Papilio polyxenes*): *a*, Larva from side; *b*, larva showing head with odoriferous appendages; *c*, male butterfly; *d*, outline of egg; *e*, young larva; *f*, chrysalis. All about natural size except *d*, which is much enlarged.

Control.—It can be hand picked successfully in the small home garden. Lead arsenate should be used in larger areas.

CELERY CATERPILLAR.

Wherever celery, parsley, carrots, or other plants of the celery family are grown, a large green or yellowish caterpillar ringed with black is sure to be found. It is known as the celery caterpillar (fig. 46) or parsley worm. It feeds normally on the leaves, but when abundant attacks blossoms and undeveloped seed. When disturbed the caterpillar gives out a powerful scent.

Control.—The conspicuous appearance of this worm makes hand picking easy. If the first brood is killed there will be little damage from the second brood. Lead arsenate can be used when necessary in large gardens devoted to a single crop of celery, parsley, or related plants.

TARNISHED PLANT-BUG.

The tarnished plant-bug (fig. 15, p. 20) is one of the worst enemies of celery. As a rule it does not do so much damage to other garden plants.

CELERY LOOPER.

The celery looper[1] somewhat resembles the cabbage looper (see p. 33) and has a similar life history. The same remedies may be employed for it, especially arsenate of lead. The loopers also may be collected by hand.

CORN.

Sweet corn is so badly infested by insects of many species that it is undesirable to plant it in many cases, considering the difficulty of obtaining good localities for its growth in small gardens.

CORN ROOT-APHIS.

The corn root-aphis is bluish green, slightly whitened by a waxy bloom. It spends most of its life feeding at the roots, but winged forms appear which migrate to various weeds, especially smartweed, mustard, pigweed, and plantain.

Control.—Crop rotation, with care not to plant in or near fields of weeds, free use of fertilizers to stimulate plant growth, and disturbing and destroying the nests of ants which attend this species and foster it by carrying the young from one plant to another are advisable. Fall plowing and late planting of corn are also useful.

SOUTHERN CORN ROOTWORM.

The larvæ, or young, of the southern corn rootworm, known as budworm and drillworm, do great damage to corn of all kinds and to several other food plants, including peanuts.

Control.—This is considered under the 12-spotted cucumber beetle, page 44. When occurring on corn, insecticides are of little value. Injury is greatest to corn when planted in damp locations and

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[1] *Autographa simplex* Guen.

in meadows. Rotate with cotton, buckwheat, and the smaller grains, and with any vegetables other than beans, peanuts, and cucurbits.

CORN EARWORM.

The corn earworm is the same species as the bollworm of cotton and the fruitworm of tomato (see figs. 79 and 80, p. 68). Ears of corn and pods of beans, cowpeas, and related plants are often found bored with holes, and the seed devoured within. This insect is also called the tobacco budworm, and it attacks pumpkins, squashes, melons, peppers, okra, and various other vegetables. Attack begins on corn in the silk, and even if only one ear is attacked this frequently leads to the entrance of other injurious insects; rain is apt to enter, and decomposition sets in. The moth which produces this caterpillar is ocher yellow in color, more or less variegated with darker markings, and measures about $1\frac{1}{2}$ inches across its spread forewings. The corn earworm itself is extremely variable in color, different shades of purple, pink, and green prevailing; it is more or less strongly striped longitudinally with black and bears prominent tubercles or warts.

Control.—Lead arsenate applied to the silk early in the season and the application repeated when found necessary will reduce the injury to some extent. Here the powder form dusted on the silk is of greatest value, but even when applied by experts not more than 50 per cent of the ears have been saved.

Crop rotation is of little value, as the insect feeds on all forms of plants, including grasses and clover, and on these plants it is seldom noticed. No variety of corn is known which is absolutely free from attack, but late sweet corn, such as Blue Flint, Stowell's Evergreen, and Country Gentleman, are less liable to injury than others.

CUTWORMS.

Cutworms and other caterpillars are often found on corn, and may be hand picked or poisoned in a vegetable garden.

FLEA-BEETLES.

Two forms of flea-beetles are commonly found on sweet corn, and they may be destroyed by lead arsenate combined with Bordeaux mixture, or Bordeaux mixture alone will repel them.

WHITE GRUBS AND WIREWORMS.

Corn is susceptible to attack by wireworms and white grubs. (See pp. 16 and 17.)

SEED-CORN MAGGOT.

See "Bean fly, or seed-corn maggot" (p. 28).

BACTERIAL BLIGHT (STEWART'S DISEASE).

In bacterial blight the affected plants die by wilting and drying up. The leaves usually wilt one after another. The plant may live for a month or die in four or five days. If a cross section is made of the stem, in about five minutes a yellowish, sticky substance will ooze out from the cut ends. The midrib of the leaves is similarly affected. Some varieties are somewhat resistant.

Rotate crops and destroy infected plants.

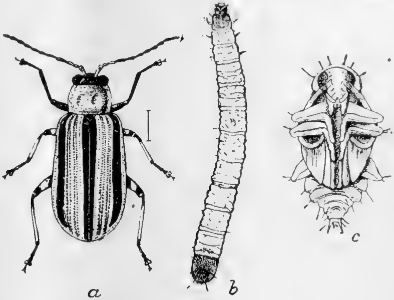

FIG. 47.—The striped cucumber beetle (*Diabrotica vittata*): *a*, Beetle; *b*, larva; *c*, pupa. Much enlarged.

SMUT.

Smut is characterized by the appearance of large, irregular boils on the ears, tassels, or other parts of the plant, covered at first with a white membrane, but later breaking open and scattering dirty masses of spores.

Cut and burn the smut boils before they burst.


FIG. 48.—Striped cucumber beetles feeding on a cucumber after frost has killed the foliage.

CUCUMBER.

STRIPED CUCUMBER BEETLE.

The striped and 12-spotted cucumber beetles occur throughout the eastern United States. In other regions several other species occur, all closely related, having very similar habits and yielding to about the same remedies. The common form is known as the striped cucumber beetle (fig. 47), sometimes called the striped bug, melon bug, or "cuke" bug. The beetle measures about three-sixteenths of an inch in length. It is yellow above, with black head and wing covers bearing three black stripes; whence the name. The worm, or larva, is slender and white-brownish at each end.

Injury is due mainly to overwintered beetles eating tender plants. They also injure older plants, eating leaves and gnawing stems and roots. The beetles usually appear in April or May. Only one generation has been observed thus far. The beetles late in the season congregate about the stems and leaves of cucurbits and later seek shelter, frequently remaining until the first cool nights of October, or later or earlier, according to season and locality. Figure 48 shows the work of this species on cucumbers. In the worm stage this species causes damage to the roots. This, however, is seldom noticed. The beetles are carriers of cucurbit wilt and mosaic disease.

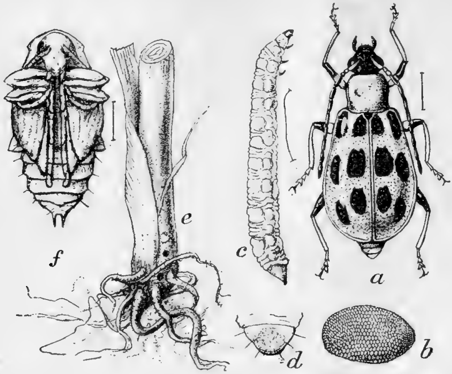

FIG. 49.—The 12-spotted cucumber beetle (*Diabrotica duodecimpunctata*): *a*, Beetle; *b*, egg; *c*, larva; *d*, anal segment of larva; *e*, work of larva at base of cornstalk; *f*, pupa. All much enlarged except *e*, which is reduced. (Riley, except *f*.)

Control.—The simplest remedy for garden use is covering young plants with a *cheesecloth-covered* frame made by cutting a barrel hoop in two, so as to form two semicircles. These are placed at right angles to each other and the lower ends sharpened and inserted in the ground with the curve uppermost. A cheap mosquito netting covering is readily penetrated by the beetles, and heavy cloth keeps out the sunlight. The lower edges must be held down by stones or other weights.

Plants may be set out as early as possible and thus avoid the beetle, although there is danger of frosts.

Another method is to plant more seed than is necessary by planting once each week in one of the squares as represented below:

1	2
3	4

The first and second plats are often killed, and sometimes the third, but as long as the insects are poisoned with lead arsenate a good stand is almost sure to be secured.

Lead arsenate as used for the Colorado potato beetle is the most useful remedy against this species. Bordeaux mixture, added to the lead arsenate, acts as a repellent and prevents injury to the foliage so treated.

TWELVE-SPOTTED CUCUMBER BEETLE.

The 12-spotted cucumber beetle (fig. 49) is a little larger than the striped species and eats practically everything, and when it occurs on cucumbers it is to be treated in the same way. The young, or larva, is known as the budworm and less commonly as the drillworm, but more properly as the southern corn rootworm. The adult, or beetle, is, perhaps, the most general feeder known, attacking "everything green." The larva, however, breeds chiefly in grasses and corn, although also on weeds and even on peanuts.

Control. — Rotation of crops, spraying with lead arsenate, and otherwise treating in the same manner as the striped cucumber beetle, are the remedies employed in small areas of cucurbits. Avoid planting in grasslands after corn and weeds.

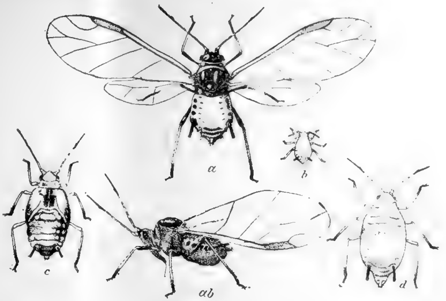

FIG. 50.—The melon aphis (*Aphis gossypii*): *a*, Winged female; *ab*, dark female, side view; *b*, young nymph, or larva; *c*, last stage of nymph; *d*, Wingless female. All much enlarged.

MELON APHIS.

The melon aphis (fig. 50), commonly called the melon "louse," injures cucumbers and other plants by piercing them and sapping their vital juices. It occurs from early

FIG. 51.—Cantaloupe leaves showing curling caused by the melon aphis. Slightly reduced.

spring and summer to late autumn and early winter on melons and other cucurbits, and on many other crop plants. In seasons which favor its increase, notably in summers following springs that are cool and rainy, it frequently appears in enormous numbers and does very serious damage, collecting in masses on the under side of the leaves of plants and causing them to curl, shrivel, and lose color, and interfering with the ultimate development of the fruit. Often it kills plants outright and destroys whole fields or greatly reduces the yield of fruit. An affected cantaloupe plant is illustrated by figure 51.

The melon aphis, like others of its kind, excretes honeydew. When this aphis becomes unusually abundant, the honeydew covers the leaves with a thin, sticky coating on which the white cast skins of the plant-lice adhere, and this attracts attention to the injury, as do also wilting and dying down of the plants. Some persons notice this honeydew and are unaware of the presence of the insects. They speak of the injury as honeydew, and have even applied this name to the insect itself.

FIG. 52.—Cucumber anthracnose.

By the time the presence of the melon aphis in injurious numbers is noticed, irreparable damage frequently has been accomplished and the insects for the most part have migrated to other pastures. This species is minute and varies from yellowish or greenish to jet black. It is generally distributed throughout the country. It finds alternate food plants in other cucurbits, cotton, okra, orange, strawberry, and some other plants, including weeds.

Control.—The best remedy is nicotine sulphate (see p. 10), which, if properly applied, will control not only this pest but the young of squash bugs, and will act to a certain extent against such soft-bodied insects as may be present at the same time.

WILT.

Wilt is usually the first disease to appear in the spring, often causing plants to wilt suddenly and die when only 6 or 8 inches tall, and it may continue to attack plants throughout the season. The disease is caused by bacteria which grow in the water vessels of the plant, thus cutting off its water supply. As the disease is carried largely by the striped cucumber beetle, the plants should be kept covered as long as possible with insect-proof cages (see "Striped cucumber beetle," p. 43) or sprayed with lead arsenate, one-half pound dry to 10 gallons of water, to kill the beetles. Diseased plants should be pulled promptly and burned or buried.

ANTHRACNOSE.

Anthracnose (fig. 52) is a disease affecting principally the leaves and stems of the plant. It causes brown spots, one-fourth to one-half inch in diameter, on the leaves, which when numerous kill them. The oldest leaves in the center of the plant are attacked first, about the latter part of July in the latitude of northern Ohio. With warm, moist weather the disease spreads rapidly, and the plants are often completely killed before the end of the season. Thorough spraying with Bordeaux mixture will hold the disease in check but will not entirely control it. Cucumbers should not be planted in the same place in succeeding years. This disease and the next may be spread by infected seed.

ANGULAR LEAF-SPOT.

Angular leaf-spot attacks the leaves in late July, causing angular spots one-sixteenth to one-eighth of an inch across, first water soaked, later sometimes whitened, and during continued wet weather it may cause considerable damage. It can be controlled largely by spraying with Bordeaux mixture.

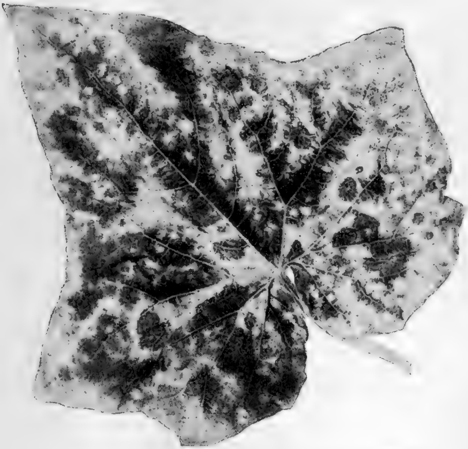

FIG. 53.—Cucumber leaf, showing mosaic disease.

MOSAIC DISEASE.

The mosaic disease, sometimes called "white pickle," occurs throughout the Middle West and causes mottling of the leaves (fig. 53), warting of the fruits (fig. 54), stunting and yellowing of the plants, and great reduction of the yield. The cause of the disease is as yet unknown, but it is certain that it is carried from plant to plant by insects, by pickers, and in other ways. It may appear as early as July 10 in the Middle West. Satisfactory control measures have not been discovered, but the plants should be kept covered with insect-proof cages as late as possible to keep insects off. Later they should be dusted with equal parts of tobacco dust and lime or sprayed with Bordeaux mixture and lead arsenate (half a pound dry to 10 gallons). See "Striped cucumber beetle" (p. 43).

DOWNY MILDEW.

Downy mildew is a fungous disease which attacks the leaves during warm, moist weather after the middle of the season, causing yellowing, with faintly defined angular spots, followed by curling and death in a few days. The oldest leaves are attacked first. If the plants are sprayed thoroughly with Bordeaux mixture every 7 to 10 days, beginning when the first symptoms of the disease appear, they can be kept in bearing condition for two or three weeks longer than unsprayed plants.

Fig. 54.—Cucumber mosaic disease, or "white pickle."

SCAB.

Scab is a fungous disease which attacks the young leaves, stems, and fruits, causing sunken, gray spots on the fruits which spoil them for use. The disease does not appear until late in the season. In moist weather it is often very severe and every fruit on a plant may be affected. Because of the rapidity of spreading under ordinary conditions and the fact that it attacks the young fruits even when in the blossom stage, it is extremely difficult to control.

GENERAL RECOMMENDATIONS FOR THE CONTROL OF CUCUMBER DISEASES IN GARDENS.

Disinfect seed by soaking five minutes in dilute formaldehyde (1 teaspoonful to 1 cup of water), wash in water, and dry or plant. Plant in hills and cover with insect-proof cages and keep these on as long as possible. If insects are troublesome when cages are removed, some will be destroyed by dusting plants with equal parts of tobacco dust and air-slaked lime or by spraying with lead arsenate (one-half pound dry or 1 pound paste to 10 gallons of water). Pull and burn or bury, as soon as found, plants having mosaic or wilt. Spray with Bordeaux mixture as soon as the first evidences of downy mildew are found.

EGGPLANT.

Eggplant is subject to the attack of the same insects as potatoes, which are treated on pages 55 to 57. After the Colorado potato beetle has attacked the first crop of potatoes, it continues work on eggplant.

EGGPLANT LACE-BUG.

The eggplant lace-bug (fig. 55) has been injurious in recent years. It feeds by sucking and sometimes is accompanied by plant-lice. Nicotine sulphate at the rate of 2 ounces to 12 gallons of water will kill all nymphs and most adults. See "Nicotine sulphate" (p. 10).

FRUIT-ROT.

Fruit-rot of eggplant is a disease occurring on the leaves and stem, as well as on the fruit, which causes it to rot rapidly. It also causes a damping-off of seedlings.

No effective control measures are known. Destroy diseased fruits or plants.

WILT.

The plants sometimes wilt suddenly and die. Pull and destroy diseased plants. Rotate.

LETTUCE.

Lettuce is attacked by the lettuce root-louse, the cabbage looper, the celery caterpillar, cutworms, thousand-legged worms, and about four species of plant-lice. Lettuce frequently watered is often free from insects.

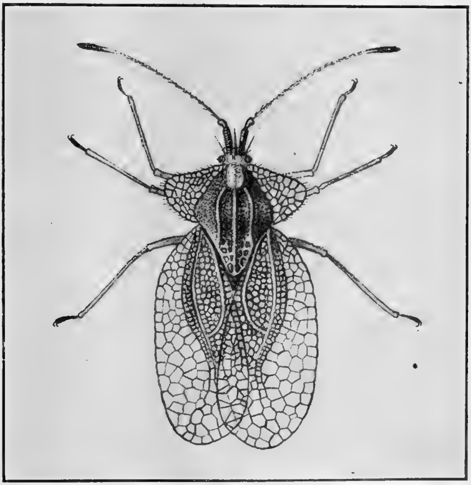

FIG. 55.—The eggplant lace-bug (*Gargaphia solani*): Adult. Greatly enlarged. (Fink.)

Control of lettuce insects.—It is extremely difficult to treat any of these pests in the garden with insecticides, because of the danger of poisoning the consumer or injuring the plants. When very young the plants may be treated safely with either arsenate of lead or nicotine sulphate, as the poisoned leaves will not be eaten.

DROP.

When plants are attacked by the disease known as drop they wilt suddenly and die. There may be found in the decaying heads small, gray to black fungous masses, or sclerotia, which remain in the soil to carry the disease over unless the plants are taken up and destroyed on the first evidence of disease.

Replant in another place.

TIPBURN.

Head lettuce often develops a browning of the leaf margins known as tipburn. This is due to the hot sun and lack of water. Prevent by watering, and make the soil rich with rotted stable manure.

Other lettuce troubles occur, but it does not pay to treat them in the home garden. Plant a new bed.

MUSKMELON OR CANTALOUPE.

Cantaloupes are affected by the same insects which attack cucumbers, the melon aphis and cucumber beetles being particularly troublesome. See "Cucumber" (p. 43).

Fig. 56.—Muskmelon leaf-spot.

LEAF DISEASES.

The spotting and death of muskmelons are usually due to one or another of three fungi, the most common being shown in figure 56. Control by spraying with Bordeaux mixture, applied first when the vines begin to run and repeated every 7 to 10 days. Rotation is important for the crop.

WILT.

See cucumber wilt, page 46.

ONION.

The onion and other bulbous crops often are affected seriously by insects in the field. The common and Welsh onions, garlic, leek, chives (or sives), and shallot are subject to attack by the same insects, but comparatively few species injure onions as a rule, the onion thrips (see p. 19) and onion maggot causing the greatest damage.

ONION THRIPS.

The onion thrips is a general pest and is considered on page 19.

THE ONION MAGGOT.[1]

Injury due to the onion maggot is the most important drawback to the culture of onions. It is accomplished by the consumption of the bulb, inducing subsequent decay of the affected portions and their very frequent destruction.

The fly and the minute maggot resemble the seed-corn maggot (fig. 57, p. 52), although averaging a little larger. The male is gray, with black bristles and hairs; it has a white face with black hairs, and there are three dark lines on the body between the wings and a row of black spots on the abdomen. The female is a little larger, inclined to dark yellowish, and has a pale yellowish face.

As in the case of the cabbage maggot, this is a northern form, and two or three generations evidently are the rule.

Control.—The methods advised for the seed-corn maggot (p. 28) frequently are about all that are necessary for this species. The tarred pads can not be conveniently or economically used on onion. The flies are probably attracted to old onion beds and to crop remnants; hence, clean field methods are always advisable. One of the best remedies is carbolic-acid emulsion (p. 8), but the best one known is a poisoned bait to attract and kill the flies. This bait is made as follows:

Sodium arsenate	ounce	⅛
Water	gallon	1
Cheap molasses	pint	1

Dissolve the arsenate of sodium in boiling water and then add the molasses. This bait has proved to be cheap, attractive, and effective. Since it is not necessary to cover the foliage, the bait may be applied in large scattering drops. An ordinary syringe, or a whisk broom dipped into a bucket of the solution and shaken about on each side of the operator, will apply the bait satisfactorily. This poisons the flies as they are attracted to the fields. Perfect stands of onions have been secured by this method—some of the best that have been secured for many years.

OTHER ONION INSECTS.

More often than not the onion maggot is accompanied by the seed-corn maggot (fig. 57), which has also been called the bean fly. Some

[1] *Pegomya cepetorum* Meade.

other root maggots are frequently injurious, as are certain wireworms (p. 17) and the tarnished plant bug (p. 19).

MILDEW.

When onions are affected with mildew the tops wither and die. A violet mildew may be seen on the diseased areas. If detected in time, spray with Bordeaux mixture and resin fish-oil soap.

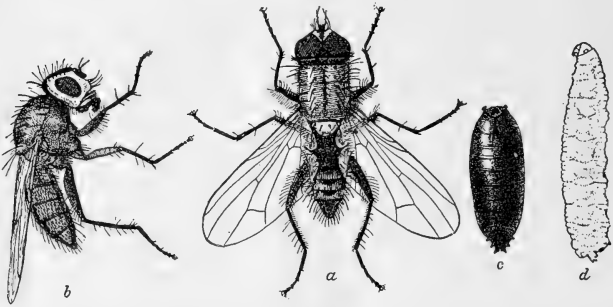

FIG. 57.—The seed-corn maggot (*Pegomya fusciceps*): *a*, Male fly, dorsal view; *b*, female, lateral view; *c*, puparium; *d*, larva, from side. All much enlarged.

SMUT.

In onion smut the young seedlings are covered with pustules filled with a black powder. This disease remains in the soil. If no clean ground can be had, apply formaldehyde solution in the drill, after dropping the seed and before covering it, at the rate of 3 to 4 quarts per 100 feet of row. Onion sets are not subject to smut injury.

PEAS.

Garden peas are attacked by the same insects as those mentioned under "Beans" (p. 25). For convenience cowpeas will be mentioned here as they are generally known throughout the South as "peas," while in the North one form is called black-eyed peas, or beans, a variety which is much cultivated for human food. Among those insects which feed on the leaves are the bean ladybird, blister beetles, and cutworms and other caterpillars. See "Beans" (p. 25). There are, however, a few insects which attack peas in preference to beans. The principal ones of these are the pea weevil and the pea aphis.

The cowpea weevil and 4-spotted bean weevil are in the same category as the pea weevil.

PEA WEEVIL.

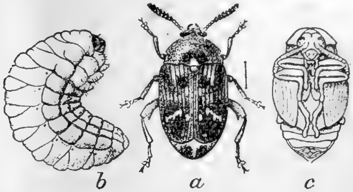

FIG. 58.—The pea weevil (*Bruchus pisorum*): *a*, Adult; *b*, larva; *c*, pupa. Much enlarged.

Seed peas often may be found with a single round hole in each, due to attack by the pea weevil (fig. 58), or "pea bug," a beetle measuring about one-fourth of an inch in length. While this insect is black in ground color, it is thickly covered with a brownish fuzz, with black and white markings. It is a pest of long standing in this country. On account of its ravages, seed peas are largely imported from Canada and the extreme northern States. Every pea in a pod when ready for the table often is infested with this weevil. The only outward appearance on the green pea to show that it contains worms is a minute dot, which seldom will be noticed. In the dry seed, however, the cell inhabited by the insect is quite plainly seen under the skin. Many weeviled seeds germinate, but they are likely to be weak and nonproductive. Since this species produces only one generation a year, it is more readily treated than are the bean and cowpea weevils.

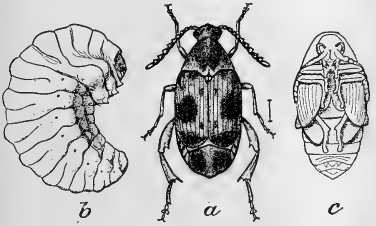

FIG. 59.—The 4-spotted bean weevil (*Bruchus quadrimaculatus*): *a*, Beetle; *b*, larva; *c*, pupa. Much enlarged.

Control.—Keep seed peas in a warm room, in a tight bag or box, one full season before planting. The weevils will issue from the seed and die. Plant late in order to secure sound seed stock. Fumigate with carbon disulphid. (See Farmers' Bulletin 799.) Do not plant weeviled or "buggy" peas, as it will not pay.

COWPEA WEEVIL AND FOUR-SPOTTED BEAN WEEVIL.

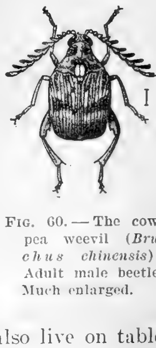

FIG. 60.—The cowpea weevil (*Bruchus chinensis*): Adult male beetle. Much enlarged.

The 4-spotted bean weevil (fig. 59) and the cowpea weevil (fig. 60) resemble each other rather closely. While both favor cowpeas as food, they also live on table beans in the South—peas, chickpeas, and, in fact, all leguminous seeds large enough for them to develop within. They differ from the true pea weevil in that they produce several generations each year on dry seed.

Control.—Fumigate with carbon disulphid. (See Farmers' Bulletin 799.)

PEA APHIS.

The pea aphis (fig. 61) is one of the larger species of plant-lice, measuring about three-sixteenths of an inch, with a total wing expanse of about four-tenths of an inch. It is uniform pea green, the same as its food plants. Attack begins on young vines, the "lice" gathering in clusters about the terminals or tips. Later they attack the stems and sap the life of the plant.

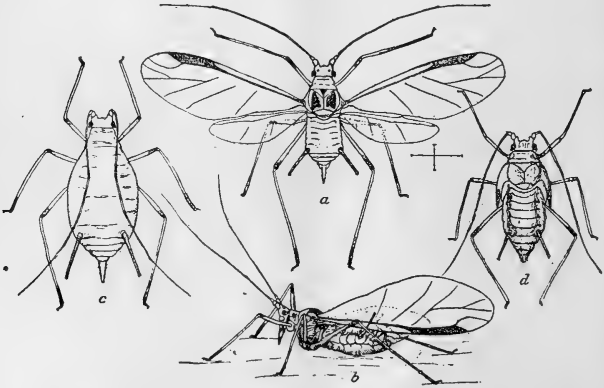

FIG. 61.—The pea aphis (*Macrosiphum pisi*) : *a*, Winged female; *b*, same from side, with wings folded in natural position, as when feeding; *c*, wingless female; *d*, nymph in last stage. Much enlarged.

Control.—Nicotine sulphate and kerosene-soap emulsion are good remedies if applied when the insect first begins attack early in the spring. If peas are grown in rows wide apart to permit a one-horse cultivator between them, the "lice" can be brushed off with boughs of pine with the leaves on, following with the cultivator immediately afterwards to bury the pest. Pine boughs also may be used by hand. Crop rotation is advisable. It appears that this insect affects practically no other garden crop than peas. Alternate plants are clover, alfalfa, field peas, and several leguminous weeds.

MILDEW.

Mildew of peas is indicated by a gray-white mold covering the leaves and pods. Dust with sulphur or spray with Bordeaux mixture.

LEAF AND POD SPOT.

Dark spots sometimes appear on leaves and pods. This trouble is known as leaf and pod spot and spreads in the seed. There is no effective treatment. Save seed from healthy pods.

STEM-BLIGHT.

When peas are affected by stem-blight the stems shrivel and decay at the soil line. Rotate.

POTATO.

COLORADO POTATO BEETLE.

If careful watch is not kept, the Colorado potato beetle (fig. 62) is certain to exact a heavy toll. This beetle and its "slugs" are so well known that no description is necessary here.

The range of this pest covers a large portion of the United States, but it is not found extensively or in especially injurious numbers

FIG. 62.—The Colorado potato beetle (*Leptinotarsa decemlineata*) and "slugs," or larvæ, at work. Slightly enlarged.

near the Rocky Mountains. It abounds from New England and Canada to Florida, westward to Texas, and in the northern Pacific region, where it has become troublesome only recently. Both the "slugs" (the young, or larvæ) and the beetles (adults) feed upon the potato plants. After passing the winter in the ground, the beetles usually appear at about the same time as the potato plants, lay their eggs, and continue feeding. They often destroy small areas, especially those grown for garden purposes. When the "slugs" of the first crop begin their work they usually finish up that begun by the over-wintered beetles, leaving only bare stems, which become dry and black. After exhausting the potato, the beetles attack eggplant and other plants of the potato family, including tomato, ground cherry, jimson weed, and related weeds. In the most northern range of this insect there is probably only one generation a year, but two generations and a partial third occur southward.

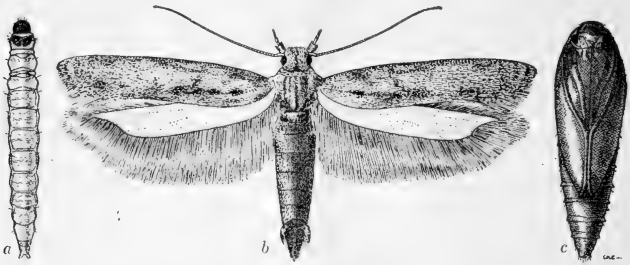

FIG. 63.—The potato tuber moth (*Phthorimaea operculella*): *a*, Larva, or "worm," seen from above; *b*, moth with wings expanded; *c*, pupa. Much enlarged. (Graf.)

Control.—Ducks, guineas, and other domestic fowls eat the beetles and larvæ. So also do snakes, toads, and skunks, which frequently gorge on them. Arsenate of lead is the best remedy, applied as advised on page 9.

BLISTER BEETLES.

Blister beetles are next in importance to the Colorado potato beetle as potato insects. They are slender, somewhat soft bodied, of various colors, and feed upon all forms of garden truck, appearing to prefer potatoes, following with beans, peas, and related crops, beets, cabbages, squashes, and others. When occurring on the potato, they are sometimes called the "old-fashioned potato bugs."

Control.—Lead arsenate is the best remedy, prepared and applied as directed for the Colorado potato beetle, but driving and burning also are useful. See "Blister beetles" (p. 17).

THE POTATO TUBER MOTH.

The larva, or "worm," of a small gray moth, the potato tuber moth (fig. 63), is the worst potato pest known in California. (See fig. 64.)

It occurs more sparingly in other States, for example in Texas and in Florida, and injures the tomato and eggplant. From its injury to tobacco it has been called the "splitworm."

Control.—For further information and control, see Farmers' Bulletin 557.

FLEA-BEETLES.

Small round holes in potato leaves and in various related crop plants, such as tomato and eggplant, show the presence of flea-beetles, which have been described on pages 35 and 36.

FIG. 64.—Potato sliced to show advanced injury by potato tuber-moth larvæ. (Graf.)

Control.—Lead arsenate applied as a spray is the most valuable remedy (see p. 9), especially when combined with Bordeaux mixture. Bordeaux mixture alone is an excellent repellent (see p. 6).

CUTWORMS.

Early potatoes are much attacked by cutworms, and frequently late potatoes suffer from the same pest. See "Cutworms" (p. 14).

WHITE GRUBS AND WIREWORMS.

White grubs and wireworms injure the tubers in the earth, which are a favorite food of these pests.

Control measures are considered under "White grubs" and "Wireworms" (pp. 16 and 17).

SCAB.

Scab is shown by rough-pitted spots due to a parasite which lives in the soil. It is spread by planting scabby potatoes. (See fig. 65.) The seed potatoes therefore should be disinfected by soaking, before cutting, $1\frac{1}{2}$ hours in a 1 to 1,000 solution of corrosive sublimate or 2 hours in formaldehyde, 1 to 240. (See p. 8.) Five and one-half gallons of the solution will cover a bushel of potatoes.

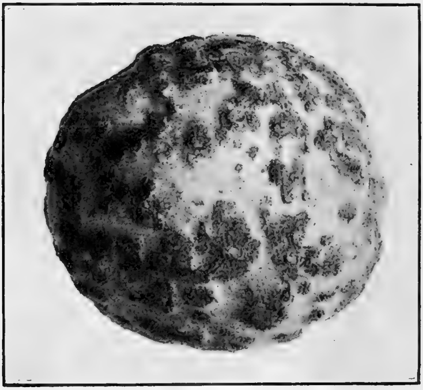

FIG. 65.—Potato scab.

When the garden has become infected, seed treatment will not prevent scab. Avoid lime, fresh stable manure, and wood ashes. Turn under green crops. Plant potatoes elsewhere if possible. Procure Farmers' Bulletin 544.

WILT AND DRY-ROT.

To guard against wilt and dry-rot, sort seed potatoes critically. Cut a slice from the stem end one-fourth inch deep, and throw out potatoes that have a deep brown discoloration. (Fig. 66.) Cut out and discard decayed parts of the tuber.

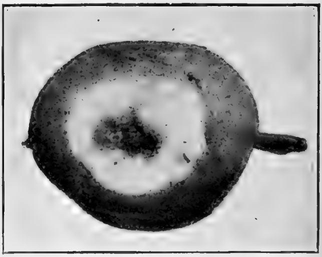

FIG. 66.—Potato stem-end browning due to the wilt fungus. Unfit for planting.

EARLY BLIGHT.

Early blight appears about midseason as dark, dead spots on the leaves. (Fig. 67.)

TIPBURN.

Tipburn is a dying of the edges of potato leaves, from too much heat and lack of water. (Fig. 68.)

LATE-BLIGHT.

Late-blight (fig. 69) is the most serious disease of potatoes in the Northern States, since it is followed by rotting of the potatoes. (Fig. 70.)

For all these foliage diseases use Bordeaux mixture, adding arsenate of lead when potato beetles are present.

For late-blight August and September sprayings are most important. It has been found profitable, however, to spray at frequent intervals throughout the season, and thus protect the plants against grasshoppers, flea-beetles, and other insects, tipburn, and early and late blight.

FIG. 67.—Potato early blight.

WEAK PLANTS.

Potatoes sometimes fail to grow vigorously, remaining small, with wrinkled or rolled leaves and bushy or spindling shoots. Several types of disease produce these effects, distinguished as leaf-roll, curly dwarf, mosaic, and spindling sprout. All are due to the planting of defective seed potatoes. From the gardener's standpoint no remedy exists and only one preventive—the securing of better seed next season. In the Central and Southern States northern-grown seed gives better results than the home grown, except when the latter is grown in the fall from northern seed.

STORAGE ROT.

Decay of potatoes after harvesting comes from two principal causes: (1) Late-blight dry-rot, resulting from failure to control the late-blight of the tops by spraying. Sort out all potatoes showing traces of dry-rot. (2) Wounds and bruises and too warm storage. Potatoes should be handled with much care and kept in a cool, dark cellar.

FIG. 68.—Potato tipburn.

FIG. 69.—Potato late-blight.

RADISH.

Radishes are attacked by the same insects as cabbages. The cabbage worms, as a rule, do less damage, but the flea-beetles, especially the striped forms,[1] sometimes are troublesome. When radish is treated with lead arsenate for cabbage worms the flea-beetles will be destroyed. This spray is recommended against the western

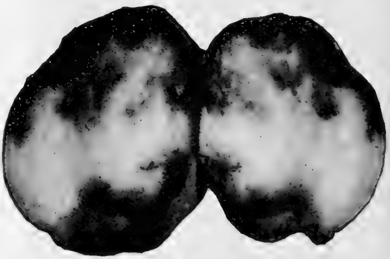

FIG. 70.—Potato late-blight tuber rot.

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[1] *Phyllotreta pusilla* Horn.

radish flea-beetle[1] in its occurrence on young seedlings. Bordeaux mixture is good as a repellent or when sprayed in combination with arsenate of lead. Bordeaux mixture is discussed on pages 6 and 7.

ROOT-BLIGHT.

Radish root-blight causes dark and shrunken areas on the roots (fig. 71). It is due to a fungus occasionally encountered in gardens. Where this occurs radishes must be moved to a disease-free spot. Beets also are subject to attack by the same fungus.

FIG. 71.—Radish root-blight.

SQUASH.

Squashes, gourds, pumpkins, and similar crops suffer from the same pests as those which attack the cucumber.

WILT.

See cucumber wilt, page 46.

COMMON SQUASH BUG.

If the plants escape the striped cucumber beetle and the melon aphis they are apt to fall a prey to the squash bug (fig. 72), commonly known as the "stink bug," from its disagreeable odor. Like the melon aphis, it feeds by extracting the juices. A brood of these insects consisting of the adults and young, of which there are five stages, may destroy many plants in a short time.

Control.—Fortunately, the common squash bug is large enough to be seen easily. Hand picking before it lays its eggs is of value. Even the eggs, being in clusters, can be crushed or cut away from the leaves. A lookout should be kept for the bugs, beginning early in the season.

Some of the remedies advised for the striped cucumber beetle, such as protecting with covers and the use of nicotine sulphate, are helpful, but the adults are difficult to kill by contact poisons. The young readily succumb, especially when they are molting or shedding their skins.

The bugs may be trapped, also, by placing on the ground, at intervals near the plants, boards, shingles, or pieces of bark or similar material under which the insects can congregate for shelter. The traps should be examined and the bugs destroyed every morning during the early season.

SQUASH-VINE BORER.

After cucurbits have made good growth they sometimes are attacked by the squash-vine borer (fig. 73), which, however, is much more destructive to pumpkins and squash, especially Hubbard and marrow cymlings, than to other cucurbits. When these borers occur on cucumbers it is almost impossible to destroy them.

Control.—The following measures may be taken: Avoid planting in or near ground in which this species has occurred. Plant early

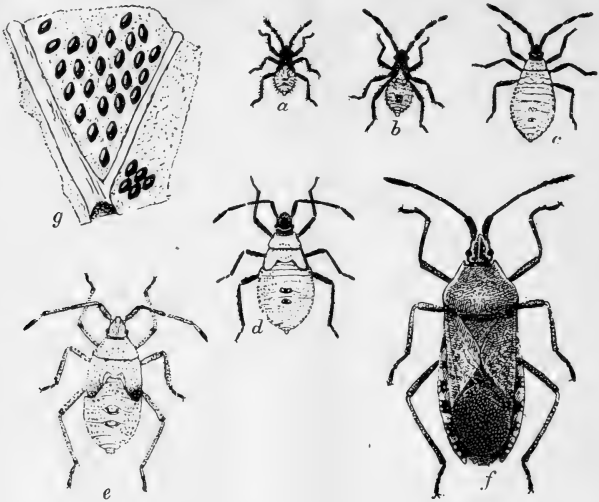

FIG. 72.—The common squash bug (*Anasa tristis*): *a*, Newly hatched nymph; *b*, second-stage nymph; *c*, third-stage nymph; *d*, fourth-stage nymph; *e*, fifth-stage nymph; *f*, adult; *g*, egg mass. All about twice natural size.

varieties of squash for a trap. Harrow the fields lightly in the fall, and plow deeply in the spring, to prevent the moths from issuing. Encourage the formation of secondary roots by covering infested stems with earth. Destroy dead vines and old plants as soon as the crop is made or whenever it becomes badly damaged. Keep plants in a vigorous condition, free from other insects and disease. Cut out borers if possible. Capture moths in sweep nets toward dark. Consult Farmers' Bulletin 668, "The Squash-Vine Borer."

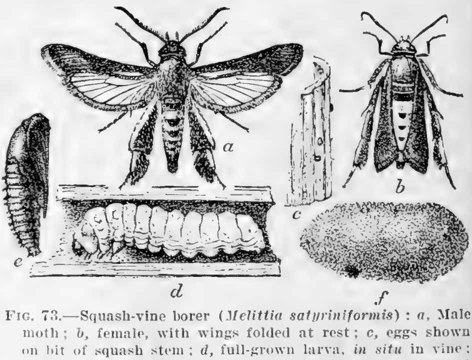

FIG. 73.—Squash-vine borer (*Melittia satyriniformis*): *a*, Male moth; *b*, female, with wings folded at rest; *c*, eggs shown on bit of squash stem; *d*, full-grown larva, *in situ* in vine; *e*, pupa; *f*, pupal cell. All one-third larger than natural size.

PICKLE AND MELON WORMS.

The pickle worm [1] and the melon worm [2] are pests in the southeastern portion of the United States and attack the fruit just before it ripens. It is practically impossible to control these insects without employing complicated measures. In small gardens paper bags may be pinned about the young fruit after it reaches the size of an egg. Since the caterpillar enters from without, the fruit is thus protected.

OTHER INSECTS.

The onion thrips, red spider, and greenhouse white fly are troublesome to cucumbers grown under glass. They can be destroyed by making smudges prepared by dipping papers into nicotine extracts. These are advertised in florists' journals.

SWEET POTATO.

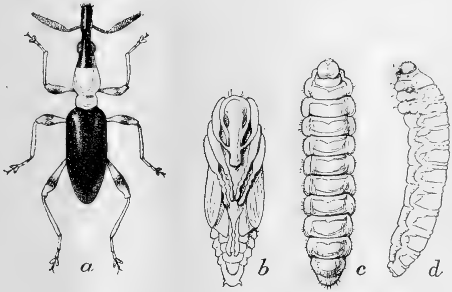

FIG. 74.—The sweet-potato weevil (*Cylas formicarius*) : *a*, Beetle ; *b*, pupa ; *c*, larva, view of back ; *d*, larva, side view. Much enlarged.

If transplanted from hotbeds the sweet potato may suffer from the attacks of cutworms and other caterpillars when first set out. Several other forms of insects attack the foliage, including blister beetles, the larvæ of sawflies, the sweet-potato flea-beetle, and the tortoise beetles. In its more northern range this crop does not suffer much loss from insect attack, but in Louisiana, Texas, and portions of Florida it is injured badly by the sweet-potato root-borer. Practically all of these insects mentioned as attacking the sweet potato breed on the morning-glory also and on other plants of this family, so that it is desirable to keep these down in the vicinity of the cultivated crop.

SWEET-POTATO WEEVIL.

The sweet-potato weevil or root-weevil (fig. 74) is confined to the Gulf region, but it has become one of our most injurious pests. The adult is a weevil with an antlike form and a decided snout or beak. It is about one-fourth of an inch long, including the snout; the wing covers are shining dark blue; the head and snout are darker blue; and the thorax and legs are dark red. The larva, or young, is grublike, about one-fourth of an inch long, whitish, with a brown head

[1] *Diaphania nitidalis* Cram. [2] *Diaphania hyalinata* L.

and darker mouth parts. The life history of this species can be passed in warm weather in about four or five weeks, and it is probable that at least four generations are produced in a year.

Control.—As the beetle practically confines itself to work on the tubers, only occasionally feeding on the foliage, the ripe tubers, as soon as found damaged, should be fumigated with carbon disulphid. (See Farmers' Bulletin 799.) Avoid curing and storage in high, moist temperatures. Badly damaged or imperfect tubers (see fig. 75) can be fed to hogs, and extremely bad ones should be burned in the field with the vines. *The utmost care should be exercised not to transport infested tubers to uninfested localities, or from an infested to an uninfested State.*

FIG. 75.—Sweet potato, showing injury by the sweet-potato weevil.

SWEET-POTATO FLEA-BEETLE.

The sweet-potato flea-beetle[1] does more harm northward. It eats out peculiar channels along the veins of both surfaces of the leaves soon after the plants are set out. Later the entire surface of the leaves becomes seared. This is the work of the beetles. The larva, or grub form, feeds at the roots of bindweed, of the sweet-potato family.

Control.—Before setting out the plants, dip them into arsenate of lead, about 1 pound to 10 gallons of water, and spray with lead arsenate a week or two later, after which a second spray may be necessary. Crop rotation also is desirable.

TORTOISE BEETLES.

Tortoise beetles of several kinds, some of them of brilliant hues, for example, the golden tortoise beetle (fig. 76) or "goldbug," rest or feed in broad daylight, when they can be captured and destroyed. When leaves are noticed to have holes in them, the beetles or their young are to be suspected. The larvæ, called "peddlers," can be picked off the lower surface of the leaves.

FALSEWORMS, OR SAWFLIES.

There are two species of sawflies, insects resembling small bees, whose young, or falseworms, injure sweet potatoes. (See fig. 77.)

[1] *Chaetocnema confinis* Cr.

They have a rather wide range, but, as a general rule, are not destructive except locally. They may be controlled by spraying with lead arsenate when they first appear.

CUTWORMS.

Since sweet potato is cultivated in seed beds, cutworms do considerable injury. Remedies are considered on pages 14 to 16.

BLACK-ROT.

Black-rot may occur on any of the underground parts of the sweet-potato plant. On the tuber it is characterized by the dark to nearly black, somewhat sunken, more or less circular spots on the surface. Although the spots are small in the early stages, under favorable conditions they enlarge, involving nearly the whole tuber.

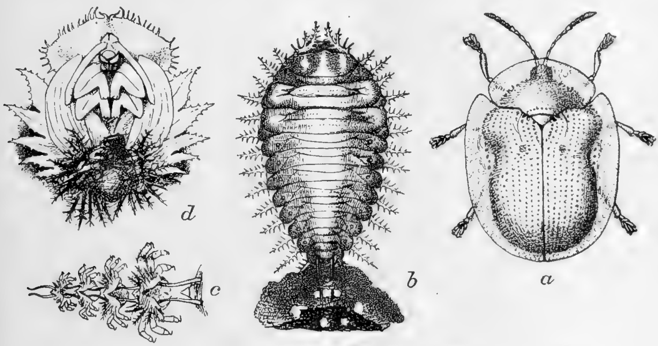

FIG. 76.—The golden tortoise beetle (*Coptocycla bicolor*): *a*, Beetle; *b*, larva; *c*, fæcifork; *d*, pupa. All enlarged.

The surface of the diseased spots has a somewhat metallic luster, and the tissue just beneath is greenish. In storage the disease spreads from one potato to another.

On the stem the infection begins as a small black spot, which enlarges gradually until the whole of the stem is rotted off. Sometimes the infected areas extend from the potato to the surface of the soil. Figure 4, page 7, shows the characteristic symptoms of this disease on a young slip. Black-rot occurs in the hotbed and in the field. It may come from the use of infected soil or from the use of infected potatoes for seed. In the latter case the fungus grows from the potato to the slips and is carried on the slips to the field. Diseased slips generally die in a few weeks in the field.

Control.—The home gardener, in buying sweet-potato plants, should make sure that they are sound and healthy. Those who grow plants for larger fields should procure Farmers' Bulletin 714, which gives directions for growing healthy plants in seed beds.

STEM-ROT.

When sweet-potato plants are affected with stem-rot, the leaves turn a dull yellow and become somewhat puckered, then wilt and die, beginning at the tip of the vine. The inner wood of the vine is blackened.

Rotate crops; secure healthy plants.

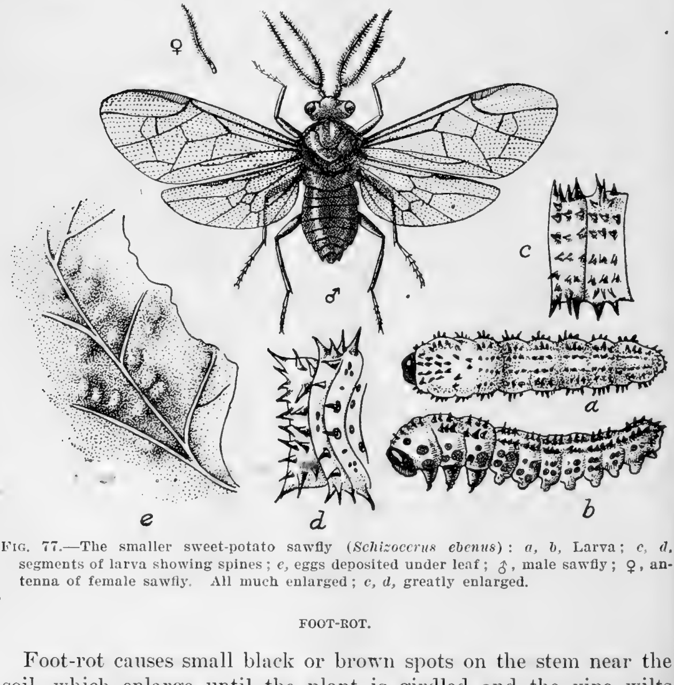

FIG. 77.—The smaller sweet-potato sawfly (*Schizocerus ebenus*): *a*, *b*, Larva; *c*, *d*, segments of larva showing spines; *e*, eggs deposited under leaf; ♂, male sawfly; ♀, antenna of female sawfly. All much enlarged; *c*, *d*, greatly enlarged.

FOOT-ROT.

Foot-rot causes small black or brown spots on the stem near the soil, which enlarge until the plant is girdled and the vine wilts and dies.

Control.—The disease is carried from the hotbed by young plants. The remedy, therefore, is to set out only plants that are healthy.

STORAGE ROT.

Decay of sweet potatoes in storage may be traced to one of the foregoing diseases or to soft-rot. This is due to wounds or bruises or to improper storage conditions. Keep sweet potatoes in a moderately cool and dry place after digging. See Farmers' Bulletin 714.

TOMATO.

The insects which attack the potato and the eggplant injure the tomato to a less extent, and tomatoes suffer greatly from other pests.

TOMATO HORNWORMS.

The tomato hornworms [1] (fig. 78) are large green worms, sometimes called tomato worms or tobacco worms, as they feed about equally well on both plants. They are the larvæ, or young, of large sphinx

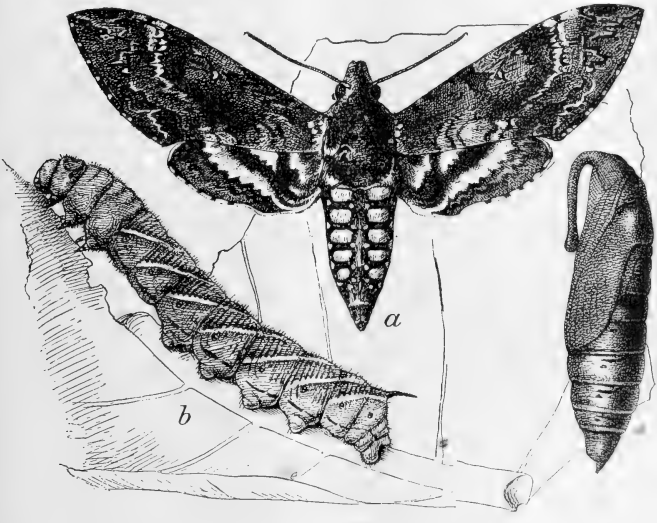

FIG. 78.—One of the tomato hornworms (*Phlegethontius sexta*) : *a*, Adult moth ; *b*, larva ; *c*, pupa. (Howard.)

moths of two species, which are very similar in habits and distribution. These insects produce two broods, and when they begin to mature they cut all the leaves from tomato plants. Growers should be on the lookout for the first as well as the second brood They appear at various times, according to the locality.

Control.—Hand picking can be practiced, but it takes an experienced eye to detect these worms when they are at rest. When feeding they are more easily seen and can be destroyed readily. A

[1] *Phlegethontius quinquemaculata* Haw. and *P. sexta* Joh.

single application of lead arsenate at the usual rate will destroy them even though crudely applied. Those which eat the poison first will be found dead the following day. The remainder will be found on the second or third day.

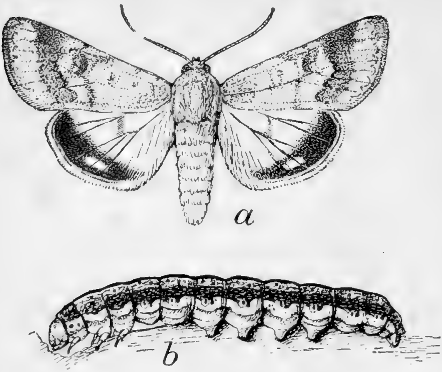

FIG. 79.—The tomato fruitworm, bollworm, or corn earworm (*Chloridea obsoleta*): *a*, Moth, or adult; *b*, larva. About natural size. (Howard.)

TOMATO FRUITWORM.

The tomato fruitworm (fig. 79) is the same insect as the bollworm of cotton and the corn earworm and is the cause of much trouble to tomato growers because of its eating into the ripening fruit (fig. 80) and destroying its market value.

Control.—Lead arsenate, 2 pounds to 25 gallons of water, applied two or three times, will keep the insect under partial control. As long as sweet corn is growing in the vicinity it attracts the worms, leaving the tomatoes less subject to attack. Hand picking is too difficult.

FIG. 80.—Characteristic work of the tomato fruitworm. (Quaintance and Brues.)

CUTWORMS.

Various cutworms attack the tomato when it is set out. Indeed, it is the favorite food plant of most forms of cutworms. For control, see pages 14 to 16.

FLEA-BEETLES.

The potato flea-beetle[1] frequently attacks tomatoes and does considerable damage.

Control.—Dipping young plants in lead-arsenate solution at the rate of 1 pound to 50 gallons of water, before setting out, will protect them considerably against injury.

Bordeaux mixture also acts as a deterrent. (See p. 6.)

[1] *Epitrix cucumeris* Harr.

LATE-BLIGHT.

A rapid blighting of the leaves, accompanied by rotting of the fruit, is due to the same fungus as that causing potato late-blight. This is common in the Appalachian region.

It is controlled by spraying with Bordeaux mixture as advised for leaf-spot.

LEAF-SPOT.

In leaf-spot, the leaves are covered with dark-brown spots (fig. 81) and shrivel and die, beginning at the base of the plant. This is the worst disease of the tomato. Spray with Bordeaux mixture and resin fish-oil soap before the disease appears and repeat at 10-day intervals. Try to spray the lower side of the leaves as well as the upper side.

FIG. 81.—Tomato leaf-spot.

MOSAIC DISEASE.

Mosaic disease crumples and distorts the leaves and produces irregular, light-green areas. The plants are weak and unfruitful. In the "fern-leaf" type the leaves become very narrow.

Mosaic disease is communicable from plant to plant by insects, especially plant-lice, and by contact. When it appears in gardens it is best to destroy the affected plants and set out others.

BLOSSOM-END ROT.

A decay of the fruit at the blossom end (fig. 82), though not understood clearly, appears to be connected with soil conditions, particularly with the water supply. To prevent it, try to make the soil well drained but retentive of moisture. Water the plants if needed. Plant the variety Bonny Best, which seems to resist blossom-end rot. Tomatoes trained to stakes and pruned often are less attacked.

WILT.

Wilt causes the plants to wilt and die suddenly. It is especially prevalent in the South, where three different forms of wilt are found. Destroy diseased plants. Use new land for the next planting.

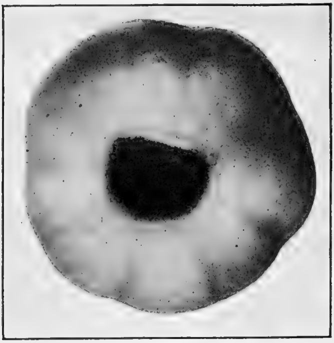

FIG. 82.—Tomato blossom-end rot.

TURNIP.

Turnips are attacked by the same insects as cabbages. (See pp. 31 to 38.)

CLUBROOT.

Clubroot of the turnip causes swollen, distorted roots similar to those caused by cabbage clubroot, which see (p. 39 and fig. 3, p. 6). Rotation and lime are advised, as for the cabbage.

WATERMELON.

Watermelons are affected by insects considered under "Cucumber" (p. 43), and great injury is done by the melon aphis (p. 45). For the control of watermelon pests, see under "Cucumber" and procure Farmers' Bulletin 821.

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SCREW-WORMS AND OTHER MAGGOTS AFFECTING ANIMALS

F. C. BISHOPP
Entomologist

and

J. D. MITCHELL AND D. C. PARMAN
Entomological Assistants
Southern Field-Crop Insect Investigations

Screw-worm fly, much enlarged.

FARMERS' BULLETIN 857

UNITED STATES DEPARTMENT OF AGRICULTURE

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

Washington, D. C. September, 1917

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THE SCREW-WORM is an important pest of nearly all stock in the Southwest. In some sections the rearing of young calves is practically prevented by its ravages. Some grown stock are killed outright and some are maimed permanently, while infested sheep always lose flesh and their milk production decreases. The expense of watching herds and treating infested animals also is considerable.

Several kinds of flies infest wounds and blow soiled wool on sheep. These flies may occur in any part of the United States.

All of these flies breed in decaying animal matter, especially in carcasses of large animals. If all dead animals could be disposed of properly, no cases of infestation of living animals would occur.

Complete destruction of carcasses by burning is the approved method. This lessens danger of the spread of such diseases as anthrax and tuberculosis from animal to animal in pastures and prevents all breeding of flies in carcasses. If burning can not be carried out properly, bury carcasses, covering them with at least 2 feet of soil. Apply a liberal quantity of quicklime prior to covering, especially if a possibility exists that the animal died of some contagious disease.

Other steps to prevent infestation are avoiding injury to stock, having calves come when flies are not abundant, destroying ticks, performing surgical operations in winter or early spring, and poisoning or trapping flies. To prevent attack of the wool-maggot, lamb early, avoid diarrhea, tag sheep if dirty, and breed hornless types.

In treating stock watch for the first signs of infestation, use chloroform to kill maggots, and follow with pine tar to repel flies.

For further information about the screw-worm fly and other flies infesting wounds, with accounts of their habits and the methods of controlling them, consult the following pages.

SCREW-WORMS AND OTHER MAGGOTS AFFECTING ANIMALS.[1]

CONTENTS.

THE so-called screw-worm[2] is a pest of prime importance to the stock raisers of the Southwest. This insect gains its common name from the habit of the larvæ or maggots of penetrating practically sound tissue. Stockmen usually distinguish between the screw-worm and what they term maggots largely by the character of the wound infested and the time of year. The screw-worm is often confused with the other species, which commonly are spoken of as maggots, especially during the spring and fall months. Injury to live stock from maggots is more widespread than is that due to the true screw-worm. In fact, this maggot injury may be found among live stock in any State of the Union, although it occurs most frequently in the warmer portions of the country. The true screw-worm inflicts enormous losses on the stock raisers of Texas, Oklahoma, New Mexico, Arizona, and southern California during seasons which are favorable for its development. During the warmer portions of the year it is never entirely absent from this region and may also cause injury to stock in the other southern States, and as far north as Nebraska.

The screw-worm is a native of the Americas and has been causing trouble to stockmen for many years. No doubt it is largely due to this fact that the cattlemen accept the pest as a necessary evil and always count upon "doctoring" a certain number of cases every year.

DISTRIBUTION AND ABUNDANCE OF THE SCREW-WORM.

The screw-worm fly occurs from the extreme southern part of South America northward into Canada, but it seldom becomes

[1] Throughout the investigations upon which this bulletin is based Mr. E. W. Laake has been associated with the authors. He was concerned especially with work on the life histories of the various animal-infesting flies, details of which will be published later. The photographs, except that of figure 5, were made by Mr. H. P. Wood.

[2] Known scientifically as *Chrysomyia macellaria* Fabricius.

abundant in the Northern States, and the fly itself is killed quickly by cold weather. Since 1843 it has been of more or less importance nearly every year in what are now the Southwestern States. At times it has become a serious pest farther to the north and east. For instance, in 1890 a rather severe outbreak was experienced in Louisiana and Mississippi, and very frequently it causes much annoyance to stock in Kansas.

In the Southeastern States cases of screw-worm injury are infrequent.

The seasonal abundance of the screw-worm fly depends largely upon climatic conditions. The first appearance of adults in numbers in spring varies from the first of April to the middle of June, according to the latitude and earliness or lateness of the season. Throughout most of the territory where it is a pest it usually becomes numerous during early May, and cases of screw-worm injury begin to appear soon after. The insect then gradually increases in numbers until the hot, dry weather of midsummer, which in Texas usually reduces the abundance so that the injury is not severe under normal conditions in the months of July and August, unless considerable cloudy and rainy weather occurs. It becomes more numerous again in the early fall, especially when the weather is warm and showery, and its activities are terminated only with the advent of heavy frosts. The abundance of this fly, of course, is dependent to a large extent upon breeding places at hand, but it is also true that a warm, humid atmosphere is best suited to its development.

CHARACTER OF INJURY AND LOSSES DUE TO THE SCREW-WORM.

Practically all animals are more or less subject to attack by the screw-worm. Probably cattle suffer most, with hogs, horses, mules, sheep, goats, and dogs following in the order named. Wild deer and many of the smaller mammals sometimes are seriously infested. Numerous cases of infestation of human beings have been recorded, and probably thousands of such cases have not been reported.

In man the nose and throat are most commonly infested, the cases occurring usually among individuals who suffer from chronic catarrh. Minor wounds on various parts of the body also are infested.

Among live stock the most common form of attack follows minor skin injuries, such as cuts by barbed wire and scratches from brush or from hooking. Sometimes calves are attacked by the worms at the time of birth. In these cases the screw-worms may enter on various parts of the body, but most commonly at the navel, where they penetrate with ease. If not promptly treated, the calf may die. Later in the life of the calves it is not infrequent to find infestations of the mouth, in some cases resulting in the loss of teeth or death.

Cows frequently are infested on regions where blood collects at the time of calving. Where ticks are abundant, a common source of infestation is through the deposition of eggs on blood spots resulting from the crushing of engorged ticks. Most of the other infestations occur following surgical operations such as dehorning, castration, branding, etc. Some cases follow serious attacks of biting flies such as the horn fly, stable fly, and horseflies. The blood oozing from the punctures made by these flies attracts the screw-worm fly. Among hogs the worms usually gain entrance about the ears and head through scratches made in fighting.

FIG. 1.—Screw-worm fly as seen from above. Much enlarged.

In cases which are not treated the injury is gradually made worse by repeated laying of fresh eggs, the number of maggots being increased enormously. In such instances the animals lose appetite immediately, become emaciated, and hide away in the brush or some out-of-the-way place. This habit increases the chances of loss by death, especially where the ground is covered by heavy chaparral.

While the death of animals is not infrequent, the major portion of the loss is due to the reduction of flesh, the time required for riding ranges and treating animals, and the money spent for screw-worm medicines. During the summer of 1914 the screw worms were so bad that many ranchers employed from 1 to 10 extra men, who were kept busy almost continuously on this line of work from May to November. A further loss of no small amount results from the practical prohibition of the breeding of cattle in certain districts, especially in parts of southwestern Texas, where stockmen have practically discontinued the attempt to raise calves and are buying up yearlings or other older animals and bringing them in for grazing.

DESCRIPTION OF THE SCREW-WORM FLY AND ITS OFFSPRING.

All flies pass through the following four changes in the course of their lives: (1) The adult or mature insect, (2) the egg, (3) the larva, which is known as the maggot or worm, and (4) the pupa, which is an inactive stage in which the change from the maggot to the adult fly takes place. The pupa stage corresponds to the chrysalis

FIG. 2.—Eggs of the screw-worm fly. Greatly enlarged.

of a butterfly. A few kinds of flies have the habit of retaining the eggs within the body until they hatch and then depositing the minute but active maggots.

THE ADULT, OR FLY.

Of the flies that breed in wounds on animals, the screw-worm is of paramount importance, and all stockmen should learn to distinguish this fly from others. It is one of the most common of the so-called blowflies in the Southwest during the summer and fall months, although in the summer it is more or less common in practically all parts of the United States. Sometimes it is spoken of by observant stockmen as the "red-head," on account of the rather conspicuous red or yellowish-red coloring of the face. It is considerably larger than the common house fly, of a dark bluish green color, with three distinct black stripes on the back between the wings, as shown in figure 1 and on the title page.

THE EGG.

The eggs of the screw-worm fly are very similar in appearance to those of other blowflies. They are about a sixteenth of an inch long and creamy white in color. Most of them are somewhat curved and have a slightly projecting double ridge along one side. (See fig. 2.) They are laid in irregular masses, sometimes several thousand being deposited in a mass by a number of females.

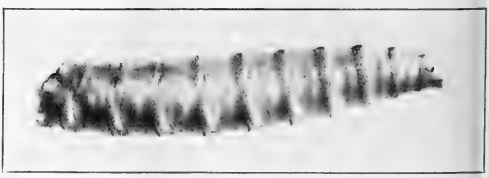

FIG. 3.—Screw-worm maggot, side view. Enlarged.

THE LARVA, OR MAGGOT.

The maggots of the flies which infest wounds of animals are all very similar in appearance. Ordinarily the differences among them can not be distinguished without a very careful examination under a microscope. Their habit of attack, however, indicates with some degree of accuracy whether they are screw-worms or some other species. All have the usual maggot shape and are nearly white. When newly hatched from the egg they are extremely minute and active, and when full grown they become nearly three-fourths of an inch long. While they have no legs, the body is fitted with minute spines and humps which enable them to crawl and aid them in working their way into an animal or any material upon which the flies are breeding. The head end is rather pointed and provided with two stout black hooks which are used in tearing the food. The larger or tail end is provided with two brownish plates through which they breathe. (See fig. 3.) It is this portion of the maggot which is seen when one observes a mass of them in a wound.

THE PUPA.

The pupa, or resting stage, usually is to be found in the ground. The pupæ are somewhat barrel shaped, with the ends rounded. They are about one-third of an inch long. (See fig. 4.) At first they are yellow, but later they turn to a rich brown color. When the fly within is mature it splits one end of the shell and crawls out.

Fig. 4.—Pupa, or resting stage, of the screw-worm. Enlarged.

LIFE HISTORY AND HABITS.

With the advent of warm weather the flies appear and begin breeding in any available decaying animal matter. The question of where screw-worm flies breed is one of greatest importance to stockmen. Many are of the opinion that they do not breed in carcasses, but aside from the few which mature in living animals this is the only medium in which breeding occurs.

The life of the adult fly is comparatively short, ranging from two to six weeks. The flies feed upon various kinds of refuse and to some extent upon the nectar of flowers. When food is not at hand and the temperature is high the flies usually die in from 24 to 48 hours. Eggs are laid in batches from one to four days apart, each mass containing from 40 to 250 eggs. A single female is capable of depositing as many as eight batches of eggs, the total number in one case being 1,228.

FIG. 5.—Screw-worm flies on weed near carcass. All vegetation around this weed was covered in a similar manner. Considerably reduced.

The eggs are deposited almost exclusively upon dead animals and in wounds. The flies show a marked tendency to visit fresh carcasses rather than old ones; this is true also to some extent with the infestation of wounds. The eggs hatch in from less than four hours when the weather is moist and warm to about two days when surroundings are less favorable. The condition which exists in fresh wounds is very favorable for incubation, and the eggs probably hatch within three hours after deposition in such situations.

As soon as the eggs hatch, the young larvæ begin penetrating the carcass, or if on living animals they start burrowing into the flesh. While undergoing development in a wound the larvæ tear the softer portions of exposed flesh with their stout jaws and excrete an irritating substance which probably assists in breaking down the tissue. When the maggots are working in a deep wound they release their hold on the flesh at intervals and come to the surface, where they lie with the breathing pores exposed. If disturbed while at the surface, they return at once to the deeper portions. The injury to the infested animal is not due entirely to the eating away of the tissues, but also to the toxic material resulting from the presence of the maggots in the wound, which may result in general poisoning of the system of the animal.

The worms grow very rapidly and in living animals are mature and drop from the wound in from four to five days. In carcasses they do not mature quite so rapidly (6 to 20 days) unless the weather is hot and damp. The grown maggots burrow into the ground to a depth of from 1 to 4 inches and soon contract, becoming first yellowish and then brown, the outside skin forming a hard protective covering. This is known as the pupa stage. The flies emerge from these pupæ in from 3 to 14 days and soon are ready for egg laying. (See fig. 5.) The entire life cycle is completed in from one to four weeks, depending on the temperature and humidity.

The multiplication of screw-worm flies would be enormous if carcasses for their breeding were present. Careful estimates indicate that as many as a million flies may be produced from the body of a single cow.

CONTROL.

The importance of destroying carcasses of all sorts of animals cannot be overestimated. If all dead animals could be burned within a few days after death, trouble from screw-worms in living animals would be unknown. It is realized fully that the obstacles to the carrying out of this method of control are many.

BURNING OR BURYING CARCASSES.

The complete destruction of all dead animals by burning is by far the best method of control. This not only stops the breeding of all blowflies but helps to prevent the dissemination of such dangerous diseases of live stock as anthrax or charbon, blackleg, and hog cholera.

The method of burning carcasses depends to some extent upon the locality. Where wood is at hand, the expense is almost negligible. It is desirable that carcasses be burnt without moving them, and *in cases of death from anthrax this is imperative.* The simplest plan is to place some wood on the ground and turn the animal over on top of it, adding fuel until the carcass is completely consumed. Burning can be facilitated by digging a small trench, placing the animal on iron rails across it, and keeping fire beneath it. If the ground is firm, the irons are not essential. A very satisfactory method where stable manure is at hand is to place a large load of dry manure on top of the carcass and set it afire. This burns slowly and usually the animal is entirely destroyed without further attention. In some districts the use of crude oil or kerosene and a small quantity of wood makes the burning quick and inexpensive. It is important that the entire carcass be consumed, as a body charred on the outside will often be more effective in breeding screw-worms than if it had not been burned at all. Complete destruction is essential also to control disease.

If burning is impracticable, carcasses may be buried. It is necessary to cover the top of the maggot-infested carcasses with at least 2 feet of closely packed soil to prevent the escape of flies. If no eggs are deposited on a dead animal it is not necessary to bury it so deep, but it is desirable to cover it well to prevent dogs or other animals from digging it up. The free use of quicklime on the carcass before covering it will destroy some of the maggots and disease germs.

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If it is absolutely impossible to burn or properly bury a carcass, many maggots can be destroyed, especially during the hot, dry weather of midsummer, by exposing the carcass in the sun. Dragging an animal into a creek bottom and leaving it in the shade of brush and trees is most conducive to screw-worm propagation. Some have suggested the cutting up of a carcass and scattering it about so as to hasten its drying. This would cause the destruction of some flies by the heat and would enable birds and other natural enemies to destroy some of the maggots, but it is really not a commendable practice.

Animals found dead in water holes should be removed at once and destroyed. Screw-worm breeding will go on unless the body is submerged completely, and there is great danger of contaminating the water with disease which may kill many healthy stock.

AVOIDING SCREW-WORM ATTACK.

Some slight modifications in the range or farm methods of handling live stock will tend to reduce the number of screw-worm cases.

CONTROL OF TIME OF CALVING.

Even in the most heavily infested districts, losses from screw-worms at calving time can be largely avoided by having the calves drop between December 1 and the middle of April. In the northern portions of the screw-worm district this time can be extended from about November 1 to June 1. Of course this changes the present common range practice of allowing bulls to remain with the herd continuously, and its successful prosecution would depend to a large extent upon having some feed at hand for use during the calving period.

TIME FOR BRANDING, MARKETING, CASTRATING, AND DEHORNING.

Under present conditions most cattlemen avoid branding and castrating during the period when screw-worms are most abundant. If all of these operations could be carried out between December 1 and May 1 very little trouble from screw-worms would follow, but the period for dehorning should be shortened to avoid maggot infestation as explained on page 4.

By rubbing a small quantity of cottonseed oil containing 4 per cent of carbolic acid over the burn immediately after branding, healing is hastened and the scab peels off smoothly.

AVOIDANCE OF INJURY TO STOCK.

It is important that all forms of injury which induce screw-worm infestation be avoided during the summer months. Greater care exercised in handling cattle will result in fewer scratches and bruises. Systematic dehorning of all cattle will largely prevent one source of injury, namely, that from hooking. This also tends to prevent some barbed wire and other scratches which result from animals endeavoring to escape the horns of others.

It is important that all corrals and pens be examined occasionally and projecting points, nails, and wire likely to cause injury to stock removed. A few minutes spent in this way will often save hours in treating screw-worm cases. Where practicable, smooth or woven wire should be substituted for barbed wire.

CLEARING OF PASTURES.

Since dense brush and undergrowth are favorable to screw-worm breeding, every effort should be made to improve this condition. While clearing of lands is more applicable to small pastures, some large stock raisers now have cleared thousands of acres of the most dense undergrowth. This procedure increases the grass production, makes the finding of dead animals or wormy animals more easy, and facilitates the handling of stock on the ranges.

DESTRUCTION OF TICKS.

A large percentage of screw-worm infestation follows tick attacks. Where systematic dipping for ticks is carried out, the number of cases of screw-worms is materially reduced. Heavy infestations of ticks other than the cattle tick[1] often are followed by an infestation of screw-worms. This is true of the Gulf Coast tick,[2] which attacks the inside of the ears of horses, mules, and cattle. While the usual system of dipping will not completely destroy this and ticks other than the cattle tick, it will reduce their numbers markedly. Furthermore, where cattle infested with screw-worms are dipped in an arsenical solution, many of the maggots are killed.

POISONING AND TRAPPING FLIES.

As supplementary measures for reducing the number of screw-worms and other blowflies, flytraps such as the hoop trap recommended by the Department of Agriculture (see Farmers' Bulletin 851) and certain poisoned baits may be utilized. By placing these traps in convenient places in the pasture, particularly near watering places, where they may be visited occasionally by riders, a large number of adult flies can be destroyed. It is best to place them on a platform slightly larger than the trap, on the side of a tree or on top of a post from 3 to 5 feet from the ground and in a place protected

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[1] *Margaropus annulatus* (Say). [2] *Amblyomma maculatum* Koch.

from strong winds and the sun. They may be baited with carcasses of freshly killed animals such as rabbits or prairie dogs. The bait should be changed every three or four days to prevent maggots from breeding in it, and the flies should be killed and emptied when the trap becomes too full.

Most liquid poisons evaporate so rapidly that they are of little use under range conditions. Where dead animals can not be promptly burned or buried it is possible to kill a large number of flies by using the carcasses as poisoned baits. The animal should be partially skinned, the flesh slashed, and a solution of arsenic made by boiling 1 pound of white arsenic in 5 gallons of water applied freely to the flesh. This method has been recommended by Prof. W. W. Froggatt in combating the sheep-maggot flies in Australia. He says that an animal will remain attractive for a couple of days only, owing to the hardening action of the arsenic on the flesh. The animal then may be turned over and treated the same way on the other side, after which it may be buried, or, if this is impossible, fly breeding is prevented by the action of the arsenical solution, and it is said that birds and animals will not touch the carcass. Small wild animals killed in pastures may be used as poisoned baits in the same way.

TREATMENT OF INFESTED ANIMALS.

It is important that herds be watched carefully during the screw-worm season so that all cases of infestation may be detected early. Those familiar with screw-worm injury have very little difficulty in telling if a wound is infested. Usually there is a free discharge of watery blood and a fresh appearance to the wound. In handling these cases on ranches it is best to have a small pasture, usually called a "trap," close to headquarters, where all infested animals are kept until the wounds are completely healed.

The construction of large cages of screen wire or netting such as shade cloth, used in covering tobacco, has been found practicable for the protection of valuable calves born in the screw-worm season. Moreover, such cages are useful for protecting injured stock from infestation or for allowing wounds already infested to heal following treatment without suffering further attack.

For destroying the maggots in a wound nothing better than chloroform has been found. One of the principal advantages of this material is that it evaporates freely and penetrates to the deeper parts of a wound. If the infested place has a comparatively small hole at the skin, but is deep, it is a common practice to pour chloroform into it and then plug the hole. In most cases it is desirable to remove the dead or comatose maggots with a pair of forceps, clean the wound out with water containing 5 per cent carbolic acid, and apply pine tar to act as a repellent for flies. Tannic acid dusted over the wound will check bleeding and make it less attractive to flies. When a wound is severe it is best to call in a competent veterinarian, especially if the infested animal is a valuable one. Turpentine, kerosene, gasoline, cobalt solution, and ether have been used with greater or less success. The former extensive use of calomel in wounds is now practically discontinued.

When it is necessary to perform any surgical operation during the fly season it is best always to apply some fly repellent. Tannic acid followed by an application of pine tar or some of the cresol dips will be found of value for this purpose.

OTHER FLIES INFESTING WOUNDS, INCLUDING THE SHEEP WOOL-MAGGOTS.

The screw-worm fly[1] is the only species in this country the larvæ of which penetrate the sound tissues of living animals. Four or five other kinds of flies have been bred from maggots taken from wounds of different types and also from soiled wool on sheep. With all of these flies there seems to be less tendency to attack fresh wounds, the attraction for them increasing as the wound becomes foul and bad odors develop.

INJURY AND LOSSES DUE TO MAGGOTS.

The injury produced by various species of fly larvæ other than the screw-worm may be divided into two classes; (1) those which attack wounds and (2) those which infest the wool of sheep, commonly spoken of as wool-maggots. The same insects may be concerned in both of these. The first type of infestation usually is to be found in large wounds or old sores. Probably the most common place of attack is in the heads of animals following dehorning, and any old festering sore may become infested. When maggots become established after dehorning, the healing process usually is greatly delayed, but it is not usual for animals to die, especially if they receive some attention. The loss due to the wool-maggot is of considerable importance. While it probably is greatest in certain sections of the Southwest, this class of injury is not uncommon in the Central States and California. One of the most serious problems with which the sheep raiser in Australia has to deal is very similar to this one, although in that region the number of different species of maggots attacking the wool of sheep is much greater and the infestation of

[1] Ox warbles cut through the unbroken skin, but the injury produced by them is entirely different from that discussed here.

flocks is more general. In this country, while a few cases occur nearly every year following lambing, it is only when favorable weather conditions prevail that the injury becomes serious. In such cases a large percentage of ewes may become infested about the rump following lambing. Some are killed outright, nearly all are cut down in flesh, and the loss in wool sometimes amounts to nearly half of the entire clip on the ewes infested. The cost of treatment and material used in destroying the maggots is considerable under such conditions.

Another common place of attack by these maggots is in the wool surrounding the horns. The blowing is usually started by the presence of slight injuries around the horns caused by fighting. Some cases of maggots follow the soiling with excrement of the wool about the vent. This usually occurs when sheep are sick and have diarrhea.

The eggs are laid on the soiled wool, and the small maggots upon hatching work into the wool. Many of them feed next to the skin, and soon the wool is loosened in large patches and the skin made red and raw. The odor from the infested area is strong, and other flies are attracted to deposit their eggs. As the irritation increases the flesh is entered, and the sheep often die.

SPECIES OF FLIES INVOLVED.

THE BLACK BLOWFLY.[1]

The fly which is responsible for most of the trouble from wool-maggots, especially in the Southwest, is the black blowfly. It is the maggot of this fly which is commonly found in old festering sores and following dehorning, except when this operation is done during the summer time in the Southwest, when the screw-worm is the species concerned.

This fly usually becomes active during warm days in the winter and multiplies rapidly in the early spring, but the hot dry weather of summer soon reduces its numbers so that in the Southwest it may disappear completely for a few months. It again increases in numbers during the fall, and after about November 1 largely takes the place of the screw-worm fly as a carrion breeder.

The adult is about the same size as the screw-worm fly, but it is greenish-black in color and has no stripes on the back. (See fig. 6.) It should not be confused with the large hairy blowfly[2] or the blue-bottle flies,[3] which are often seen in or around houses during the fall,

[1] *Phormia regina* Meigen. [2] *Cynomyia cadaverina* Desv. [3] *Calliphora* spp.

winter, or early spring months. These blowflies usually are larger in size, more hairy in appearance, and have grayish colored thoraxes and dark-blue or silvery blue abdomens.

The breeding habits of the black blowfly are very similar to those of the screw-worm fly. It is exclusively a flesh breeder, but occasionally it may develop in very old decaying carcasses. The eggs, which are deposited in masses, hatch in from less than 24 hours to 4 days. The maggots become fully developed in 3 or 4 days after hatching and begin to crawl away and burrow into the earth. The pupa stage lasts from 7 to 10 days, and after the fly emerges a week or more usually elapses before the first eggs are laid. On living animals the rate of development is probably somewhat faster. By this rapid breeding the flies may become very abundant during the early fall before cold weather sets in.

THE GREEN-BOTTLE FLY.[1]

The green-bottle fly has a wide distribution throughout the world. It is known as the green-bottle or green blowfly in this country. It is rather closely associated with habitations of man and is not as commonly found on the range as are the screw-worm fly and the black blowfly. It is often abundant in cities, especially if garbage is not properly cared for.

This is the fly which causes the wool-maggot of sheep in the British Isles, and the same habit has been recorded for it in this country. It has been known to deposit eggs on the soiled rumps of calves as well as sheep, following diarrhea, and occasionally it infests wounds on animals, but it is not as injurious as are the two species previously described.

It is usually slightly smaller than the black blowfly and the

FIG. 6.—The black blowfly or common wool-maggot fly of the United States, as seen from above. Enlarged.

[1] *Lucilia sericata* Meigen.

FIG. 7.—The green-bottle fly. Enlarged.

screw-worm fly. (See fig. 7.) Its color ranges from a brilliant bluish green to a dark metallic bronze green. It is without stripes or other markings.

The adult flies usually appear during the first warm days of spring and are present throughout the summer, though they seldom become as numerous as the screw-worm fly or black blowfly. The length of time required for development is about the same as that required by the black blowfly. The maggots breed exclusively in animal matter.

THE GRAY FLESH FLIES.

There are two or more species[1] of this group of flies which occasionally breed in living animals, apparently attacking only old festering wounds. They are of comparatively little importance, and since there are a great number of different kinds of flies of this group, some of which are not at all injurious, it is hardly necessary that the stockmen learn to recognize them. Their size varies considerably from a little larger than the common house fly to somewhat larger than the black blowfly. The color usually is uniformly gray, with black stripes on the back. One of these flies is shown in figure 8.

Many of the members of this group of flies retain the eggs in the abdomen until they hatch, and thus bring forth living maggots. Those species which attack living animals breed in decaying animal matter and their life history is almost the same as that of the screw-worm fly. The flies seldom become very numerous, and in most of the cases in which they are found in living animals they are located in old festering wounds or the young are deposited after a sore has become infested by screw-worms. These flies seem to be able to withstand the hot, dry weather of midsummer in the Southwest and probably are responsible for many of the cases of infestation of animals during such periods.

METHOD OF CONTROLLING MAGGOTS.

The black blowfly, the bluebottle fly, and the flesh flies are carrion breeders. They attack wounds on living animals mainly as a result of the presence of the flies in abnormally large numbers. Therefore it

[1] *Sarcophaga texana* Aldrich, *S. tuberosa* var. *sarraceniodes* Aldrich, and *S. robusta* Aldrich.

is clear that practically all of the methods of control recommended for the screw-worm are equally applicable to the other species of noxious flies. To prevent the breeding of the black blowfly it is essential that carcasses be burned or buried, even during the winter months. Thus the proper disposal of carcasses becomes of much importance all the year. Where these flies become a nuisance by contaminating food products or by entering houses, which is usual in towns or cities, attention must be given to the proper disposal of garbage, as they will breed in the meat scraps in garbage cans or on dumps as well as in carcasses.

THE TREATMENT OF MAGGOTS IN WOUNDS.

To destroy maggots in sores the same method as for the screw-worm is to be followed. It is not always possible to prevent maggot infestation following dehorning, but if periods of cool weather in winter are chosen for this operation, usually no trouble follows. To prevent maggots from gaining entrance to wounds the application of pine tar is advised. Following dehorning, some advise covering the wounds with pieces of cloth dipped in pine tar. Many of these will remain in place several days.

The tails of lambs are sometimes infested by maggots following docking. This can be largely prevented by removing the tails with moderately heated pincers. The docking of lambs also tends to avoid soiling of the wool during succeeding months, and this helps to prevent infestation of the rump by maggots. Other important steps in preventing wool-maggot injury are the following: (1) Breed hornless sheep and thus avoid injury from horns and consequent infestation around them; (2) lamb as early in the spring as possible—considering other conditions; (3) shear either before lambing or as soon after as possible, and thus avoid the infestations which almost invariably follow in heavy-wool sheep when warm, humid weather comes on.

FIG. 8.—A gray flesh fly (*Sarcophaga* sp.) Enlarged.

In Australia very extensive work has been done looking toward the destruction of maggots in wool, but nearly all the remedies devised have serious objections, so that dependence must be placed almost entirely upon preventive measures. If sheep become infested, however, the wool should be clipped from about the portions containing the maggots. It is necessary to begin the clipping outside the infested area, so as to avoid driving the maggots back into the unsoiled wool and thus extending the trouble. When the maggots have been concentrated in a certain spot by clipping around them, the application of stock dip in concentrated form or the use of chloroform, especially if the infested area is covered immediately with a piece of oilcloth, will destroy the maggots, and the entire mass then can be clipped off. Mixtures of turpentine and tar have been tried in Australia for the destruction of wool maggots and the prevention of subsequent infestation, with a fair degree of success. It is important that something be applied to deodorize the infested parts and hasten healing. Some sheepmen use air-slaked lime dusted lightly over the parts to dry up the discharge and reduce the odor. This undoubtedly is accomplished to some extent, but there is some danger of forming crusts and having maggots infest the sore places or wounds beneath these.

On large sheep ranges, when the lambing is done during seasons which are favorable for infestations, it is best to have the flocks divided into rather small units and carefully watched, so that any fly-blown sheep may receive immediate attention.

To protect lambs and other sheep during the summer months from being blown by bluebottle flies an effort should be made to prevent diarrhea, and when sheep get dirty they should be promptly trimmed up. Apply to the rump, and to the parts fouled by diarrhea, grease containing a few drops of crude carbolic acid or tar oil. The grease will hold the tarry odor in suspense and act as a fly repellent.

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CRANBERRY INSECT PROBLEMS AND SUGGESTIONS FOR SOLVING THEM

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AN ABUNDANT water supply, permitting flooding and reflooding at the proper times, is the best remedy for insect injury in cranberry bogs, and when the sites of new bogs are to be chosen this should always be borne in mind. On cranberry land where the water supply is insufficient, however, spraying, sanding, and other measures will have to be used.

The cranberry has many insect enemies, but some of them are of importance only on dry bogs. The foliage is attacked by three species of "fireworms," the tipworm, spanworms, army worms, and the cranberry fleabeetle; the fruit is eaten by the fruitworm, blossom worm, cranberry katydid, and grasshoppers; the vine is attacked by the girdler, toadbug, vinehopper, spittle insect, mealybug, and Putnam and oyster-shell scales; and the roots are destroyed by the rootworm and white grubs. This bulletin gives brief descriptions of these pests, their life histories, and the means found most effective, in each case, in preventing their ravages and destroying them.

CRANBERRY INSECT PROBLEMS AND SUGGESTIONS FOR SOLVING THEM.[1]

CONTENTS.

COMMERCIAL CRANBERRY CULTURE is an intensely specialized industry, limited to a few sections of this country, notably areas in Massachusetts, New Jersey, Wisconsin, Long Island, and a district along the coast near the mouth of the Columbia River in the Pacific Northwest. Troublesome insects occur in all these regions, most of which are also of economic importance on other plants.

Cranberry bogs usually are flooded in the wintertime, from December or January until April or May, and reflowed one or more times in the spring to eradicate insects. Occasionally a bog is flooded in the fall, immediately after picking, for a period of one or two weeks, a practice which aids materially in controlling the pests.

Insect problems may be disposed of with little difficulty where the bogs are constructed properly and ample provision is made for flooding and reflooding. Many bogs, however, have been laid out without supplying adequate flooding facilities, and hence the control of insects has become a very serious problem for some growers. New insecticides are coming to the front, and these may be of value in helping to control cranberry insects, but too much stress can not be laid upon careful provision for a water supply when plans are being made for the development of cranberry land.

[1] This bulletin supersedes Farmers' Bulletin 178, Insects Injurious in Cranberry Culture.

FOLIAGE-ATTACKING INSECTS.

BLACKHEAD FIREWORM.[1]

Three distinct species of the so-called fireworms—the blackhead, the yellowhead, and the red striped—are known to infest cranberry vines. Of these the blackhead fireworm is by far the most injurious. It causes very large losses annually in New Jersey and is well known for its destructiveness in Massachusetts, Wisconsin, Long Island, and the Pacific Northwest.

Character of Injury.

Injury produced by the three species of fireworms is very similar, but inspection of the webbed foliage soon will reveal the worms, disclosing whether the blackhead or one of the other kinds is at work, the distinction being indicated by the terms used as their common names.

Blackhead fireworms feed on various parts of the plant at different periods in their development, the total damage in cases of severe infestation finally giving to the vines a burnt appearance, which justifies the term "fireworms." The young worm, or larva, of the first brood usually burrows into the lower side of one of the lower leaves and for several days acts as a leaf miner (see fig. 1), after which it crawls to the tip of the upright and either bores into the unopened bud or makes a web, joining one or more of the terminal leaves to the bud, beneath which it feeds. As soon as new shoots of the vines are forced out the worm attacks the young leaves, webbing the topmost together (fig. 2), so that in its feeding it

Fig. 1.—Blackhead fireworm: Frass or castings over mines of newly hatched larvæ in cranberry leaves.

[1] *Rhopobota vacciniana* Pack.

is protected fairly well from its natural enemies. At this period a very good idea may be had of the acreage infested and the abundance of the worms.

Destruction of the terminal buds by the first brood causes a shortage of the crop and on many bogs the shortage amounts to practically the total crop of the area badly infested. First-brood feeding causes some browning of the foliage and a temporary checking of growth, but before the second brood appears the vines will put forth a considerable amount of fresh, green foliage.


FIG. 2.—Blackhead fireworm: Cranberry tips webbed by first brood of larvæ.

Second-brood worms appear in July and attack the new foliage as well as many of the leaves of the previous season, webbing them up so as to include in some cases several uprights. (Fig. 3.) In addition these worms eat blossoms and bore into many of the newly developed berries. The work of this brood gives to the bog a burnt appearance.

In late summer the vines again start to grow, some of the uprights producing buds that will fruit the following season, but the crop from these is likely to be a short one. Many of the chewed and skeletonized leaves drop from the vines, leaving the uprights bare except for some late growth at the tip.

Description and Seasonal History.

THE EGG.

This insect passes the winter in the egg stage. In July and August the moths place the eggs on the underside, rarely on the upper side of the cranberry leaves. For the most part the eggs are deposited fairly close to the ground, frequently on leaves springing from delicate and spindling uprights deep within the vines. The egg is flattened, disklike, yellow, and about one thirty-second of an inch in greatest diameter.

Hatching may take place in the following spring as early as April 20 on dry bogs, on vines exposed above the winter flowage, or on vines submerged in shallow water. If the winter flowage is removed May 10, eggs will be found hatching from that date until the latter part of May. Deep flowage and heavy vine growth tend to delay the time of hatching. After the worm has emerged the eggshell

FIG. 3.—Blackhead fireworm: Webbing of cranberry shoots by second brood of larvæ.

appears shining whitish. The eggs of the second brood, appearing on the vines in late June and early July, require 5 or more days for hatching.

THE LARVA.

The larva is a dark green worm with shining black head and neck and measures about one-half inch in length. From the time of hatching, as indicated above, until growth is completed, about 18 or more days are required in the case of the first brood; the time required for the second-brood worms averages between 14 and 15 days. If the winter flowage is removed May 10, full-grown worms may be found the latter part of the month, although the majority will not reach full size until early June.

THE PUPA.

When the time for changing into the chrysalis arrives the habit of the worm varies somewhat in the cranberry districts. In the Eastern States the pupa will be found on the ground among fallen leaves or trash, usually naked, but sometimes in a lightly constructed web of silk woven on the surface of a fallen leaf. In Wisconsin the pupa is more often found in the webbed tips of uprights. The pupa is of various shades of brown, becoming nearly black just before the emergence of the moth. The pupa period of the first brood averages about 13 days, and in the second brood it is shortened to an average of 10 days.

THE MOTH.

The adult (fig. 4) is very small, measuring not more than one-half inch across the expanded wings, and is grayish brown. The forewings are marked with alternate light and dark bands of gray-brown shade. The moths fly little in the early part of the day, but at dusk they may be seen in their jerky flight going short distances a foot or two above the vines. Egg laying may occur within 24 hours after the emergence of the female.

FIG. 4.—Blackhead fireworm: Moth, or adult. Much enlarged.

SEASONAL ABUNDANCE OF LARVÆ.

Where the winter flowage is removed April 10, worms will be found in maximum numbers during the periods April 25–May 20 and June 18–July 10. Should the flowage be removed May 10, the periods of destructiveness will approximate May 15–June 10 and July 6–July 25.

TREATMENT.

REFLOWING.

When properly timed, reflowing is the most effective method of clearing a bog of fireworms. The best results are obtained if the flowage is applied when the worms are about full grown, as at that time they succumb in fewer hours than when they are newly hatched. In the pupa stage not less than 4 days' reflowage is required to exterminate them. Just after hatching, when the worm is burrowing into a leaf, instances have been observed where 5 days of reflowing failed to kill.

One of the commonest and gravest mistakes in reflowing for this pest is the holding of the flowage for too short a period.

FIG. 5.—Improper reflowing of cranberry bog. Nearly every tip bears blackhead fireworms.

Holding of the winter flowage until May 10, followed by reflowage about May 28, keeping the vines completely covered for not less than 48 hours, has proved a very satisfactory method of ridding New Jersey bogs of fireworms. If the worms are very abundant, however, they will be likely to destroy all of the crop during the period May 10–May 28 by their feeding in the buds. This may be prevented in large measure by a preliminary reflowing for 48 hours, or by spraying, about May 17, with nicotine sulphate. (See formula under "Spraying," p. 9.)

If it is necessary to draw the winter flowage in early April, two reflows should be made where practicable, one about May 15, for 72 hours, and one about June 1, for 36 hours.

LATE HOLDING OF THE WINTER FLOWAGE.

Where the winter flowage was held until June 1 this method of treating worms on level, shallow-flowed bogs was found successful. It is essential, however, to keep the water just over the tips and to mow or burn any exposed tips. (Fig. 5.) The warmth of the shallow water causes hatching of the eggs under water and eventual drowning of the small worms.

On the other hand, a deeply flooded bog is known upon which considerable hatching of fireworm eggs occurred after the removal of the winter flowage, June 18.

SPRAYING.

After repeated failures in the control of the worms with arsenical sprays, such as arsenate of lead, arsenite of lime and Paris green, and with arsenicals applied as dusts, these materials have been discarded in favor of 40 per cent nicotine sulphate. This insecticide has a wide usage for insect pests and recently has been found of value against fireworms. It is not known definitely at this writing to what extent it will be effective where reflowing can not be practiced, but it has given very marked results in conjunction with reflowing.

For bogs without reflowage two applications are suggested after drawing the winter flowage May 10. Make one application about May 17 and a second application one week later.

Preparation of the nicotine-sulphate spray.—The proportions found effective in killing the blackhead fireworms are 1 part of 40 per cent nicotine sulphate to 800 parts of water. The material may be used much stronger without causing injury to vines or fruit, but the control of the worms will not be appreciably better. The addition of 2 pounds of fish-oil soap aids in spreading the insecticide. This spray should be applied as a moderately fine mist, about 200 gallons being used per acre, and it being borne in mind that it is mainly effective as a contact poison and not as a stomach poison.

For good results this spray must be applied when the small worms are in or near the tops of the uprights just before growth of new foliage is made. Once the worms become webbed up in leaves of the current season, the spray will not be so effective, because it will be impossible to wet many of them at that time.

YELLOWHEAD FIREWORM.[1]

The yellowhead fireworm is often troublesome in New Jersey but is of minor importance at present in other cranberry regions. As an apple pest it is known widely throughout this country. Its

[1] *Peronea minuta* Rob.

FIG. 6.—Yellowhead fireworm: Early-season work of the larvæ on cranberry.

control is an easy matter in most instances, and its presence in considerable numbers on a cranberry bog is usually an indication that the bog was planned without sufficient regard for proper flowage.

CHARACTER OF INJURY.

Injury resulting from the feeding of these fireworms is similar to that of the blackheads, causing the vines to appear as if fire swept. The foliage is webbed in much the same manner, permitting the worms to feed with some protection. The vines shown in figure 6 are typical of the work of the early broods, and those shown in figure 7 represent vine appearance in September, at which time much of the fruit is found wormy (fig. 8). Crates of berries may be noticed in storage houses late in September and during October that are infested with these worms, which sometimes are mistaken for the true cranberry fruitworm.

DESCRIPTION AND SEASONAL HISTORY.

This species is peculiar in that the appearance of the moth in summer is very different from that which it assumes in the fall and winter. The moths that develop in the fall are of a reddish gray color (fig. 9) and, notwithstanding the rigors of the climate, pass the winter hidden among vines or brush or sometimes in cranberry houses, although on warm, bright days they may be seen on the wing.

About April 1, egg laying begins, and the succeeding generations of moths are orange red in color (fig. 10). The moths are a little larger than the moths of the blackhead fireworm, and the same may be said of the worms. The lighter color of the worm and its shining yellow head serve readily to distinguish this pest from other fireworms. The eggs are yellow and under a lens will be found marked off into irregular hexagonal figures.

The pupa is dark brown to blackish, with a very prominent knob at the head extremity. It may be found in a silken cell among webbed uprights.

During the course of some experiments carried on in New Jersey in 1914, three generations of moths of the orange-red form were pro-

FIG. 7.—Yellowhead fireworm: Late injury to cranberry vines and fruit by larvæ.

duced prior to the last generation, which is of the gray color, thus showing that in New Jersey, at least, four generations may occur, although three should be considered normal.

The early broods of worms develop on dry bogs, or on the upland, or on flowed bogs where some of the vines are not covered by winter flowage. They are likely to go unnoticed, and steps to combat them are seldom taken until the berry feeding and extensive webbing of the later broods is begun. The last brood is slower of development and will be found infesting fruit to a considerable extent in September and October.

FIG. 8.—Yellowhead fireworm: Work of larvæ on cranberries.

TREATMENT.

LATE HOLDING OF THE WINTER FLOWAGE.

Bogs can be readily cleared of yellowheads

Fig. 9.—Yellowhead fireworm: Moth, or parent insect, gray form. Much enlarged.

by holding the winter flowage one season until May 10. If this is done, the wintering moths will be compelled to lay their eggs on the upland, and very rarely will the worms of the succeeding generations work their way back to the bogs.

Parts of bogs that can not be winter-flowed are undesirable holdings and are better if left unplanted. They serve as breeding places for a number of undesirable insects.

SPRAYING.

Arsenical poisons are reputed to be more effective against yellowheads than against blackheads. Arsenate of lead at the rate of from 3 to 5 pounds of the paste to 50 gallons of water is recommended for application as soon as newly hatched worms are discovered. In view of the surprising success obtained in the control of the latter worms with 40 per cent nicotine sulphate, however, the suggestion is offered that growers who have dry bogs infested with yellowheads spray them twice at intervals of a week just before new leaves begin to appear at the tips of the uprights, using 40 per cent nicotine sulphate (1 to 800) at the rate of 200 gallons per acre. (See directions for preparation of nicotine sulphate, p. 9.)

RED-STRIPED FIREWORM.[1]

At the time of the publication of Farmers' Bulletin 178, "Insects Injurious in Cranberry Culture," it was thought that the red-striped individuals noted among infestations of yellowhead fireworms were simply a variety of the latter species. This conclusion has been shown to be erroneous, and in both Massachusetts and New Jersey it has been found that the red-striped worms develop into moths of a distinct species.

This pest will be found almost invariably along with yellowhead infestations, the conditions for one being suitable for the development of the other. It is essen-

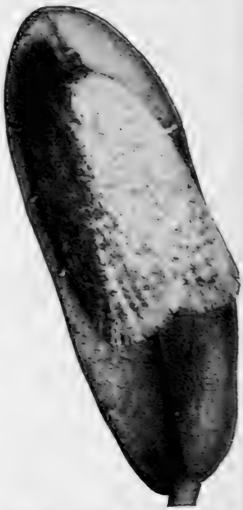

Fig. 10.—Yellowhead fireworm: Moth, or parent insect, orange-red form. Much enlarged.

[1] *Gelechia trialbamaculella* Cham.

tially a dry-bog species, occurring also on the upland as a rather extensive feeder on the huckleberry and blueberry.[1]

Description and Seasonal History.

Hibernation of the red-striped worms differs from that of the other fireworms in that the winter is passed in the worm stage. In late fall

Fig. 11.—Red-striped fireworm: Work of larvæ on cranberry.

the worm becomes dormant in a narrow, tubular case of frass-covered silk, formed in the uprights among badly mangled leaves (fig. 11), and remains therein until the following spring. Most of these bunches of brown, webbed leaves, with the encased worms, drop to the ground during the winter. Emergence of the moths begins in May and a second generation of moths appears in July and early August. The moth is dark brown with white face and three small

[1] Notably *Vaccinium corymbosum.*

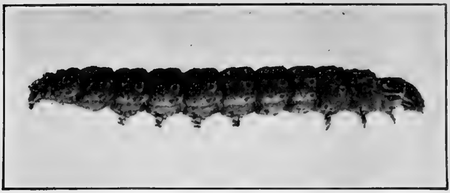

FIG. 12.—Red-striped fireworm: Larva. Considerably enlarged.

white dots on each forewing. Under a hand lens other smaller white spots may be seen dotted over the wings.

Hibernating worms are parasitized heavily and can not withstand winter flowage. Narrow red stripes running longitudinally along the body (fig. 12) serve to distinguish them from the other fireworms. The worm always lives in a somewhat loosely constructed case among the foliage, and, when full grown, uses the case for a cocoon in which to pass the pupal stage.

The eggs are pearl white, very small, irregular in outline, but very plastic. They are placed under loose pieces of bark on the woody parts of the vines, beneath dormant buds, and in the axils of leaves. (Fig. 13.)

TREATMENT.

WINTER FLOWAGE.

Bogs that can be winter-flowed so that all portions are covered are not troubled by red-striped fireworms.

SPRAYING.

This pest will rarely be detected on the vines until mid-August, at which time an application of paste arsenate of lead (3 pounds to 50 gallons of water) should suffice to control it.

CRANBERRY TIPWORM.[1]

The cranberry tipworm appears to be one of the most common and most generally distributed of cranberry insects, although the extent of its injury is not appreciated fully. It has caused serious losses in Massachusetts and its injuriousness is coming to be recognized more fully in New Jersey. Reports of its work have been received recently from the Pacific coast cranberry district and it is a pest long established in Wisconsin. Until recently its life history was a matter of much conjecture, but lately some of the obscure points have been cleared up.

[1] *Dasyneura vaccinii* Smith.

Character of Injury.

The work of the first brood of tipworms, occurring in May and June, is of little consequence as compared with that of the later brood, occurring in July. In both instances the topmost leaves, usually two small ones facing each other, become cupped, their tips bending toward each other and their external surfaces appearing whitish. This result is effected by the feeding of the maggots on the interior surfaces of the leaves, where they rasp the issues with a peculiar horny process on the underside of the body, causing the cell contents to flow so that they may be absorbed through the mouths of the tipworms.

The topmost leaves die and sooner or later break off, leaving a black stub. (Fig. 14.) New growth springs up to replace the old, but about the time it attains an inch or two the attack is repeated by the next brood of tipworms.

When the first brood is at work the growing tip is killed above the point where the blossoms have started, so that the crop of the current season is not affected appreciably; but the July brood of worms destroys many tips upon which no new growth or buds are produced, consequently no fruit develops on these uprights the succeeding year. On the other hand, two or more buds are occasionally found springing from an injured upright, all of which develop fruit.

A considerable number of counts and observations show, however, that buds springing from the sides of injured tips produce little fruit in comparison with buds borne at the terminals of the uprights. In other words, side buds usually develop into leaf shoots, which is particularly true on weak-vined bogs or bogs lacking in plant food.

Runners and uprights, alike, are attacked, the injury to the former serving rather as a mild form of pruning.

Fig. 13. — Red-striped fireworm: Eggs on woody part of cranberry vines. Much enlarged.

Description and Seasonal History.

The manner in which this species passes the winter was long a subject of conjecture, but recent studies have shown that the worms of the

FIG. 14.—Cranberry tipworm: Tips of uprights killed by tipworms.

last brood descend to the ground to form their cocoons and remain there until the following spring. Thus hibernation occurs on the bog and is not affected appreciably by ordinary holding of the winter flowage. The hibernating cocoon is a very small, whitish, flattened oval case of closely spun silk and usually will be found attached to a fallen leaf or bit of trash, but also may be found fastened to a woody stem a few inches above the ground. The cocoons of the first brood of worms appearing in the spring occur in the damaged leaves at the tips of uprights or runners.

In the late spring the orange-red or yellowish grub (fig. 15) changes into a brown pupa and shortly before the time for the fly to emerge the pupa works its way out of the cocoon through a slit at one end. The adult is a very delicate, two-winged fly whose extended wings measure not more than an eight of an inch from tip to tip. (Fig. 16).

The eggs are colorless, very slender, slightly curved, almost microscopic, and have been seen to be deposited on leaf surfaces at the tips of the uprights.

Two generations are known in Massachusetts, and present information indicates that in New Jersey the insect is commonly of two generations, although a partial third perhaps may develop upon bogs from which the winter flowage is drawn early.

TREATMENT.

SANDING.

Extensive observations made on certain Massachusetts bogs, by Dr. H. J. Franklin, have shown that infestations may be reduced to a minimum by sanding the bog lightly every other year. Bog conditions in New Jersey are so different, however, that a much heavier coat of sand would be required on many of the bogs, owing to the fact that they were prepared originally without sanding, and that resanding is not a common practice. If sanding is to prove a success as a control measure, it must be applied thoroughly, covering all of the litter beneath the vines at least one-half inch.

Fig. 15.—Cranberry tipworm: Injury to cranberry tip by larvæ. Much enlarged.

REFLOWAGE.

The usually efficacious method of clearing worms from a bog by reflowage does not meet with success in killing tipworms, because these tiny maggots can withstand submergence for a longer period than that during which it is safe to have the growing vines covered.

Well-nourished vines generally recover better from tipworm injury than weak and neglected vines; and from the results of recent experiments there is some reason to believe that an application of commercial fertilizer, particularly on savanna land, is helpful in enabling the vines to set buds after a tipworm attack.

Fig. 16.—Cranberry tipworm: Adult fly. Much enlarged.

SPANWORMS.

Looping, or measuring, worms, otherwise known as spanworms, are periodically abundant, but probably are more injurious on Massachusetts bogs than on those of any of the other cranberry sections. Recently in New Jersey they practically have not been known to cause serious injury.

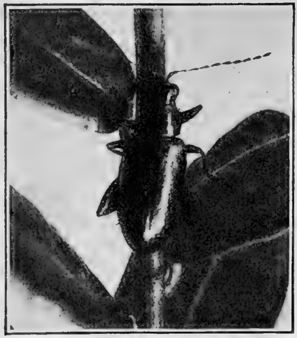

Fig. 17.—Cranberry fleabeetle: Adult, or beetle. Much enlarged.

Four or five species are known to be of economic importance to the cranberry, and the fact that an outbreak may develop unexpectedly during any summer is a strong reason for frequent inspections of the bogs. When at rest among the vines and foliage the worms are difficult of detection and it is only when they start into motion that they are readily noted.

An ordinary insect-collecting net, the appearance of which in the hands of a man afield is often the subject for much merriment, should have a place, nevertheless, as part of the equipment of every cranberry bog. Sweeping the vines with a net is one of the surest ways of detecting an unsuspected insect infestation and this practice will aid in the discovery of invasions of spanworms.

The customary treatment for these insects is the application of a spray of arsenate of lead or Paris green.

ARMY WORM AND FALL ARMY WORM.

In seasons of army-worm[1] abundance it is not an unusual thing to find these worms infesting cranberry bogs. As a general rule they prefer grasses for food and will feed upon them if the bog is not a clean one, before doing much feeding on the vines. There are times, however, when the vine feeding becomes a serious matter and a remedy is sorely needed.

Another worm, very similar to the true army worm and known as the fall army worm,[2] is likely to cause severe losses on bogs from which the winter flowage is removed in July. The moths advancing northward from the Southern States appear to be attracted to bogs recently bared of the flowage and there they lay their eggs in preference to adjoining bogs from which the flowage was removed at the normal time.

Where practicable a prompt reflowage, preferably during cloudy weather, will suffice to kill or drive either of the above species to the shore, where they may be destroyed by the use of a knapsack sprayer delivering a spray of burning kerosene. If reflowage can not be practiced, either the poisoned-bran bait as recommended in this bul-

[1] *Cirphis unipuncta* Haw.

[2] *Laphygma frugiperda* S. & A.

letin for grasshoppers (p. 27) or spraying with some arsenical may be found serviceable in reducing the numbers of the insects.

CRANBERRY FLEABEETLE.[1]

On young plantings the small, black beetle with red head, known as the cranberry fleabeetle (fig. 17), is often disastrously injurious.

FIG. 18.—Cranberry flea-beetle: Injury to cranberry foliage and fruit.

During the summer following the setting out of new vines the beetles attack the leaves, more often the lower sides, eating off the tissue but leaving the veins, so that the leaves appear to have been skeletonized. (Fig. 18.) This feeding may be so severe as to render replanting

[1] *Systena frontalis* Fab.

necessary the next season. Older vines are attacked, but with less serious consequences.

The beetles first appear on the bogs and on brush along the dams during early July and remain throughout the summer. Indeed it is not unusual to find them feeding in the early part of October. Egg laying begins in late July, with deposition just below the surface of the ground. Hatching takes place the following May, but nothing is known of the habits of the little grubs on cranberry bogs except that they remain in the soil and are not thought to be extensive feeders on cranberry roots.

TREATMENT.

Experiments conducted in cages have shown that the beetles feed ravenously upon unsprayed vines, but leave almost untouched those sprayed with Bordeaux mixture and arsenate of lead. When spraying bog areas it is customary to omit spraying the young plantings, because they are not expected to bear fruit; but probably it would pay well to spray these sections with Bordeaux mixture and arsenate of lead (3 pounds of the paste or $1\frac{1}{2}$ pounds of the powder to 50 gallons of Bordeaux mixture) when the usual rot sprays are applied. Leaves of young vines often are noted in badly diseased condition due to the attack of one of the rot diseases of the cranberry fruit and it is therefore doubly important to spray them where the foregoing insect and fungous troubles prevail.

FRUIT-ATTACKING INSECTS.

CRANBERRY FRUITWORM.[1]

Probably the most troublesome insect enemy of the cranberry in Massachusetts and Wisconsin, and one which causes heavy losses of fruit annually, is the cranberry fruitworm. In New Jersey the pest is of minor importance, although each season it may be found in scattering numbers throughout the cranberry region. The reason for its scarcity in New Jersey is not clear. Apparently conditions are favorable for its development in large numbers, but as a matter of fact the fruitworm is of so little importance in that State that the growers are not finding remedial measures necessary. There is only one brood, but, owing to the manner of feeding and hibernation of the larvæ, successful control is very difficult.

Character of Injury.

The first sign of its work, premature coloring of the berries, is well known to most growers. Upon hatching, the larva goes to some point near the stem end of the berry, burrows into the flesh, and closes

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[1] *Mineola vaccinii* Riley.

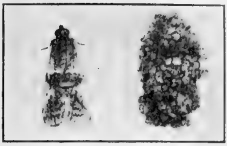

FIG. 19. — Cranberry fruit-worm: At right, cocoon; at left, moth. About twice enlarged.

the entrance hole with a thin, silken web. The seeds are eaten and usually some of the pulp in the first berry, after which the berry is vacated and the larva attacks another.

The berry turns red prematurely soon after it is attacked, and gradually shrivels, but may hang on the vine until another spring. The entrance to the first two or three berries is closed by a silken web, unless the worm can fasten adjacent berries together and thus pass from one to another without exposing itself to the attack of parasites. The number of berries destroyed varies with their size, but most of the pulp is eaten in all except the first.

Frequently larvæ that are late in maturing are carried in the berries into the warehouses, and in some cases the number has been so great that a large part of the crop has been ruined in storage.

Description and Seasonal History.

HIBERNATION.

Upon completing its feeding the larva descends to the sand under the vines on or near the surface of which it spins an oval cocoon about five-sixteenths of an inch long (fig. 19, at right). The cocoon usually is composed of grains of sand held together with strands of silk, but lacking sand the worm will not refuse peat or trash for this purpose. Each year a few larvæ spin up within the last berry which they attack. Although the cocoons are not impervious to water, the larvæ hibernate successfully under the customary winter flowage. Hibernation begins in August and continues until the following June or July.

THE LARVA.

The newly hatched larva usually enters the berry near the stem end, but most berries, after the first two, are entered at the side, and in only the first two or three is the entrance closed.

The larvæ are active from about July 1 to August 30, but also may be found in September within the berries. At this time the worm measures slightly more than half an inch in length and is green, tinged with red on the back. The head is yellowish, with brown mouth parts. A few sparse, long hairs clothe the body. (Fig. 20.)

THE PUPA.

In the pupa stage the insect is at first whitish but soon changes to yellow and a few days before emergence to dark brown. Pupation commences within the cocoons in late May and June on winter-flowed bogs and slightly earlier on dry bogs.

THE ADULT.

Moths appear in numbers on the bogs in July and fly for a period of about a month. They hide among the vines during the day but become quite active in the evening. The forewings are dark ash gray, with a distinct pinkish tinge, and mottled with white and blackish. Two dark dots on a whitish patch near the front margin of each forewing will aid in recognizing this pest. The hind wings and the underside of both pairs are shining grayish brown. (Fig. 19, at left.)

THE EGG.

The egg is flattened, disklike to oval in outline, and so plastic when laid that it adapts itself readily to any irregularity of the surface on which it is deposited. In appearance, at first white, then watery

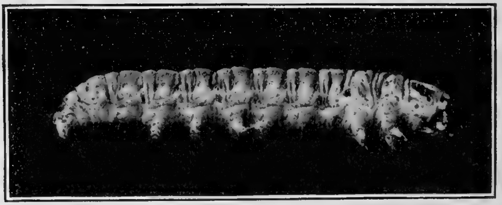

FIG. 20.—Cranberry fruitworm: Larva. Much enlarged.

translucent, they soon become pale yellow. The eggs usually are deposited in the calyx cup under the lobes, but they may be on any part of the berry. The period of incubation is about 5 days, but may be prolonged to 8 days in one which is parasitized.

TREATMENT.

Spraying with arsenicals has been tried repeatedly for the control of the fruitworm, but with so little success that it can not be recommended.

Growers very generally recognize that late holding of the winter flowage serves to keep fruitworms in check: the evidence in Massachusetts is that holding the flowage until May 20 will prove beneficial if practiced every other year. The early application of the winter flowage in the fall has not proved as valuable as the late holding in the spring. Recent studies of Dr. H. J. Franklin at the Massachusetts State Bog have shown that fall flooding after picking is of considerable value in destroying fruit worms.

In the case of a bog that has become unprofitable or is barely paying its way, owing to its infestation by fruitworms and other insects, it probably would be found most satisfactory to hold the winter flowage until July 1, or even mid-July, thereby sacrificing whatever berries might have been harvested.

CRANBERRY BLOSSOM WORM.[1]

The cranberry blossom worm is a recently discovered cranberry pest in New Jersey, injury from this particular species not having been reported from other cranberry sections. There is little doubt, however, that the blossom worm has been causing losses, at least on New Jersey cranberry bogs, for many years; and, though its injury may have been noted from time to time, no attempt appears to have been made until recently to study the insect or to control it. It is apparent, also, that the amount of loss occasioned by the feeding of this insect has not been given due consideration, and it is not realized how great this loss may be.

Character of Injury.

Feeding is at first confined to skeletonizing the leaves or eating pieces out of the leaves, beginning at the margin and working toward the midrib, or boring into the buds, thus spoiling them for fruit production. The insect might be termed a budworm, since it destroys many of the buds, but its feeding becomes more noticeable in the blossoming season, when it cuts off the blossoms near where the stem joins the flower, and the ground then may be found littered with severed flowers. This habit of the worm is very wasteful of food, because many more blossoms are cut off than are consumed after the worm again goes to the ground.

Sometimes small round holes are bored into the young berries, but the worm does not remain within the fruit, as does the fruitworm. During the remainder of the season the eating of tender foliage is continued until growth is completed in late summer.

Description and Seasonal History.

Worms first appear on the bogs in late May and early June, hatching from eggs deposited the previous fall on the litter beneath the vines. Winter flowage appears to have no detrimental effect on the eggs and does not prevent them from hatching. Feeding continues, as outlined above, throughout the summer, and probably most of it is done at night, since the worms usually are found concealed in the trash in the daytime. The full-grown worm is about an inch in length, chocolate brown, with the head shining light brown. A whitish stripe runs lengthwise along each side of the smooth and well-rounded body (fig. 21).

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[1] *Epiglaea apiata* Grote.

FIG. 21.—Cranberry blossom worm: Two larvæ. Enlarged.

Transformation to the pupa stage takes place in early September in deep trash or in an earthen cell slightly below the surface of the ground. The chrysalis is plump, brown, and measures about five-eighths of an inch in length.

Emergence of the moths begins in late September, and many will be on the wing in early October. The moth (fig. 22) is reddish brown above and slightly lighter in shade below. The forewings are marked with a few fine lines and irregular figures in dark brown. The thorax is tufted heavily, the hairs rising on the dorsal part to form a short keel. These months are of considerable size, measuring $1\frac{1}{2}$ inches between the tips of the wings, and can be caught readily and recognized if one is watching for insect pests in October.

Egg laying is at its height in mid-October, and the moths are prolific layers. The egg is whitish, nearly round, except for a slight flattening at one end. The sides are deeply corrugated vertically. A few that have been collected on the bog under natural conditions were found firmly fastened to fallen leaves (fig. 23).

TREATMENT.

SPRAYING.

In the control of blossom worms very satisfactory results were obtained from a heavy application of arsenite of lime on June 30. Since the use of this form of arsenical is attended with some risk to the health of the vines, it is preferable to use some other arsenical, such as arsenate of lead. Apply the latter poison at the rate of 3 pounds of the paste or $1\frac{1}{2}$ pounds of the powder to 50 gallons of water. This material is frequently used on cranberry vines with the addition of 2 pounds of resin-fishoil soap.

FIG. 22.—Cranberry blossom worm: Moth, or parent. Considerably enlarged.

REFLOWING.

Where water is available for fall reflowing, a great deal of good may be accomplished by flooding the bog for one week immediately after picking the crop. If the water is applied in October, when the moths have emerged from the ground and are resting among the vines, the flood will catch them as it rises and their death will follow in a day or two. Once the moth gets into the water it seems unable to free itself and soon perishes. It is probable that fall flooding also destroys the pupæ.

The spring reflow, if it can be applied in June for 48 hours, will serve to control blossom worms.

CRANBERRY KATYDID.[1]

Much of the damage to the fruit of the cranberry attributed to the feeding of grasshoppers must be charged to the cranberry katydid. New Jersey bogs still seem to be the favorite haunt of this insect and it ruins a large amount of fruit annually in its efforts to obtain the seeds of the growing berries. Naturally much of the pulp is removed in this operation, but for the most part it is rejected and falls to the ground. What is left of the berry, a mere shell, remains clinging to the vine in a shriveled condition, giving evidence of the nature of the culprit.

FIG. 23.—Cranberry blossom worm: Egg on cranberry leaf. Much enlarged.

The mature katydid is green, with exceedingly long hind legs and antennæ. At rest the semitransparent wings are folded close to the body and in this position the insect will measure about 1¾ inches from the head to the tips of the wings. The sound-producing instrument is borne only by the male and is at the base of the forewings, where they overlap. The female may be recognized easily by the sickle-shaped apparatus, at the end of the abdomen, by means of which the eggs are laid.

Young katydids first appear on the bogs about the middle of June but do not attain their full size until August. The berry-feeding habit is developed to full extent about the middle of July, when the insect has reached the stage immediately preceding the adult. Egg laying occurs in September and October, after which the adults die. Infestation of the succeeding year develops from the wintering eggs. These are laid in the blades of grasses, chiefly those known locally as "double seeded millet"[2] and "deer grass."[3]

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[1] *Scudderia texensis* S. & P. [2] *Panicum viscidum.* [3] *Panicum dichotomum.*

The outline of the egg in a blade of millet may be seen by holding the blade to the light and the egg also can be detected by the slight swelling around the place of insertion. The egg is much flattened, kidney shaped, yellowish brown, and about three-sixteenths of an inch long. The shell is marked with figures ranging from regular hexagons on the flat sides of the egg to ovals and circles on the rounded edges. When placing the egg the female glues it to the inner walls of the grass blade and no portion of it may be seen from the outside.

TREATMENT.

Formerly it was inferred that the eggs would not survive winter flowage, but it has been demonstrated recently that the contrary is the case. Eggs found on a bog in double-seeded millet hatched the following June, after a winter of submergence lasting from December 1 to May 10.

Since the katydids do not lay eggs in cranberry leaves but select chiefly the blades of double-seeded millet and deer grass for the purpose, neither of these grasses should be allowed to grow either on the bogs or along the dams. For clearing dams of grasses a form of torch delivering a spray of burning kerosene will be found effective.

GRASSHOPPERS AND CRICKETS.

Much interest is manifested in grasshoppers and crickets by cranberry growers and many assertions are heard each year as to the quantity of berries that these insects destroy on various bogs. The most recent investigations dealing with these pests have shown that several of the common short-horned grasshoppers can and do eat cranberries on the vines in considerable quantities. Not only do they finish up berries that have been opened by katydids, but they open up sound berries and eat freely of the pulp. Grasshopper feeding gives to the berry the appearance of having been roughly gouged, while katydid feeding is deeper and leaves the berry more cleanly hollowed out.

Feeding tests of the short-horned grasshoppers indicate that two species in particular[1] go readily upon the vines and eat berries. These two species are very common throughout the cranberry district of New Jersey and often have been noted in large numbers on certain grassy and weedy bogs.

Meadow or long-horned grasshoppers undoubtedly destroy many berries on ill-kept bogs, but there is no evidence to show that crickets will attack berries on the vines, although they have been known to feed on berries on the ground. Crickets lay their eggs along the

[1] *Schistocerca alutacea* Harr. and *Melanoplus bivittatus* Say.

sandy dams and sandy spots in the bogs, but the meadow grasshoppers lay theirs in the stems of sedges, rushes, and large grasses.

A number of growers contend that although the great injury to the cranberry crop wrought by the katydid is rightly recognized, too little importance has been laid upon the injuriousness of both the short and the long horned grasshoppers. The contention appears to be well founded.

Treatment.

The most effective way to keep a bog free of grasshoppers is to keep it free of grasses and plants other than cranberry. Weedy bogs are the only ones that suffer appreciable losses from grasshopper feeding, and a bog inhabited annually by large numbers of grasshoppers can not become a source of profit until it is free of them.

Aside from those bogs which are so overspread with undesirable growth that they require a complete drowning out lasting at least two years, there are others in which it would be profitable to hold the winter flowage until mid-July of one season in order to get rid of some of the objectionable weeds. This latter treatment also would be effective in clearing the bog of the grasshoppers and crickets for a season or two, and this condition could be made permanent by carrying out methods of better culture. Many of the grassy bogs need better drainage, more ditches, some pruning, and some sanding.

POISONED-BRAN BAIT.

Very effective results in the killing of grasshopers have been obtained in various parts of the United States by broadcasting poisoned-bran bait. One instance is known in New Jersey where this material proved of great value in destroying grasshoppers on a cranberry bog, and, although its use on bogs has been very limited, it is deserving of further trials. The formula for its preparation is as follows: Wheat bran, 25 pounds; Paris green, 1 pound, or white arsenic, 1 pound; lemons or oranges, 6 fruits; low-grade molasses, 2 quarts; water, 3 gallons.

Mix the bran and poison while dry; add the molasses, the juice of the fruit, and the finely chopped pulp and rind of the fruit to the water. Pour the resulting liquid over the poisoned bran and stir well to dampen it thoroughly. This amount of material should be broadcasted over 5 acres of bog, making the application late in the evening, or, preferably, very early in the morning, as at this time the grasshoppers are just beginning to feed. The bait is not attractive to the insects when dry, and two applications should be made, two days apart. In mixing the bran and poison use a spade or other implement, so as to avoid absorption of the poison by the hands and forearms. The damp mash may be sown with the bare hands.

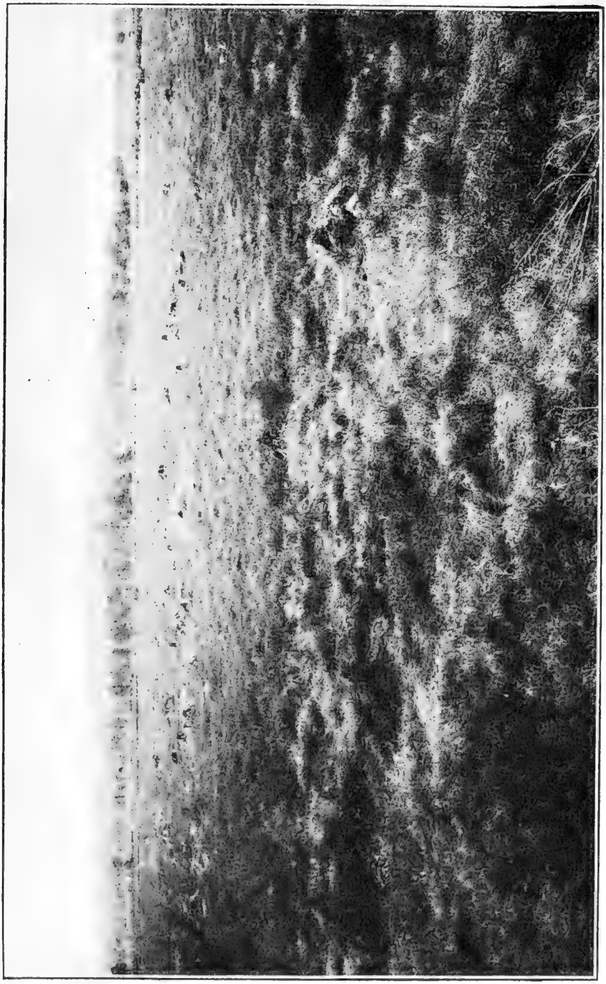

FIG. 24.—Work of the cranberry girdler in cranberry bog. The vines in the foreground have been largely killed by this insect.

VINE-ATTACKING INSECTS.

CRANBERRY GIRDLER.[1]

The cranberry girdler is the most destructive of insects that attack the vines and is the cause of large losses each year, particularly in New Jersey. Although the pest is rather common in Wisconsin, the damage on cranberry bogs in that State has not been severe, probably because the marshes are, as a rule, wetter than those in the Eastern States. The girdler is distributed widely throughout the United States and other countries and is known to many as a pest of grasses.

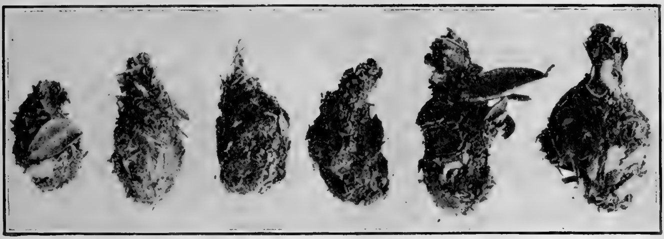

FIG. 25.—Cranberry girdler: Cocoons. Enlarged.

Its known food plants are few, however, and it seems to have become more destructive to cranberry than to any other crop. The work of this insect on the bogs is very noticeable, but owing to the concealed feeding habit of the worms few growers ever find them and not infrequently the damage is attributed to other causes and steps to control the worms are not taken.

CHARACTER OF INJURY.

Injury to the vines is caused by the feeding of the worms on the stems and runners and, to some extent, on the roots. Not only is the bark eaten but the wood itself is gnawed, frequently resulting in the complete severing of a runner. The plant at its crown is very liable to be girdled, resulting in quick death of the leaves and branches beyond. The feeding marks are usually associated with quantities of castings, or excrement, more or less held together by strands of silk.

The character of the injury is such that large areas of the vines may be killed in the course of a single season, and if the worms are left unchecked these areas will grow larger from year to year. (Fig. 24.) Entire bogs are rarely, if ever, attacked. There appear to be certain parts of every bog, particularly the higher and well-drained parts, where the vines are underlain with large quantities of trash, which are more favorable for girdler development and it is

[1] *Crambus hortuellus* Hübner.

these areas which suffer most. Where the injury is less severe the killed spots may range from 2 or 3 feet in diameter to areas of a square rod or more. After the second year the tendency is for the smaller spots to become revined, but this is in all cases a slow process. Even a severe infestation seldom is detected until late summer, when the foliage of the injured vines assumes a reddish cast, but in the fall the injured areas are very noticeable with their red and brown leaves and lifeless vines. The following spring most of the leaves will have shattered, leaving areas of naked, dead vines.

Description and Seasonal History.

HIBERNATION AND PERIOD OF COCOONING.

After completing its feeding in the early fall the worm forms a cocoon (fig. 25), composed of bits of trash from the bog floor, sometimes largely of pieces of twigs and leaves and sometimes of sand, lined with silk. The cocoon is formed in the trash itself, and, being of the same character as the trash, is very difficult to find. It is not impervious to water and, in fact, becomes full of water within three or four days after the turning on of the winter flowage, but the worm is not injured by such treatment.

The importance of obtaining the correct date for the period of cocooning can not be overestimated, because upon it depends the success or failure of the fall flooding. In New Jersey the period when the worms make their cocoons begins about the last week in September and is at its height during the first week in October.

THE MOTH.

Upon the removal of the winter flowage in the spring the change from the larva to the pupa occurs within 2 or 3 weeks, and this in turn is followed shortly by the emergence of the moth from the cocoon. For example, if the winter flowage is removed May 10,

FIG. 26.—Cranberry girdler: Moth, or parent insect. Much enlarged.

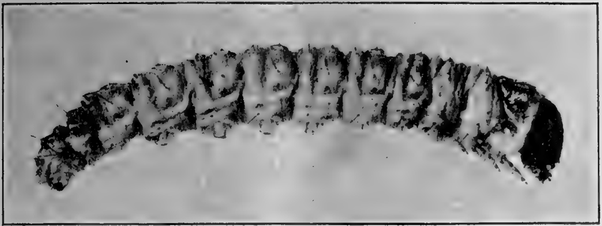

FIG. 27.—Cranberry girdler: Larva. Much enlarged.

pupæ will be found in the cocoons early in June and moths will be emerging in large numbers about June 15. The adult (fig. 26) measures about three-fifths of an inch in maximum wing expanse. Flying about the bog it has a whitish appearance, but in reality the ground color of the forewings is pale straw, bearing touches of brown, silver, and black, with a fringe of silver. The hind wings are silvery gray.

ONE GENERATION ONLY.

Moths may be seen flying on the bogs from May until August, and it has been thought by many persons that at least two generations occur in a season. This, however, is not the case, there being only one brood of worms a year. On dry bogs the moths may be expected to emerge in May and June, and in some spots on flowed bogs where the vine growth is especially heavy, and where, perhaps, the water has been slow in draining, emergence of moths will not take place until July. These late-emerging moths may fly for several weeks and thus give the appearance of a second brood. The moths are prolific layers, dropping their eggs on the trash beneath the vines.

THE EGG.

The eggs are white at first, becoming pink and then red as hatching approaches; they are oval in outline and slightly flattened at the poles, with ribs running vertically from pole to pole. Owing to their minute size, it is practically impossible to find them on the trash.

THE LARVA.

The newly hatched larva is an active, hairy specimen and almost never is encountered owing to its minuteness, dirty color, and the fact that it works in the fallen leaves beneath the vines, where the finding of a full-grown worm is indeed difficult. Early feeding seems to be of little importance, but in August and September the worms are ravenuous feeders, consuming large amounts of bark and wood.

FIG. 28.—Cranberry toadbug: Short-winged form of adult. Much enlarged.

They work almost entirely in the layer of trash which covers the runners and will not be found beneath the surface of the soil itself. The mature worm (fig. 27) measures about five-eighths of an inch and has a body of a pale, smoky color, with a brown head.

TREATMENT.

FALL FLOODING.

The treatment which gives the most complete control, amounting practically to extermination of the worms, is the fall flooding of the bog for a period of one week, beginning the latter part of September and certainly not later than the first week in October. The object is to get the water on the bog while the worms are naked and before they have formed cocoons. If flooding is practiced after the worms have cocooned, the water may be kept on the bog all winter without injuring them. The difficulty in carrying out this method of control is either a lack of storage water or the lateness in ripening of the fruit.

LATE HOLDING OF THE WINTER FLOWAGE.

Maintaining the winter flowage until July 20, with the consequent loss of the current season's crop, is the method frequently used to check severe infestations. If disastrous frosts are not met the following year, the crop of that year may be expected to be about double that of a normal season. Holding the winter flowage until July 1 permits some of the moths to emerge from their cocoons, but holding until August 1 is likely to prevent a good set of buds for the following year.

SPRING REFLOWING.

No dependence can be placed on spring reflows as a control measure against the cranberry girdler, even on those lasting as long as 5 days during the period of pupation.

SANDING.

Many bogs can not be fall flooded, and on some the winter flowage can not be held until July 20. For these there seems to be no recourse but sanding, which preferably is done in late fall, but may be done on the ice or in early spring. On many of the unsanded bogs where the trash is heavy little benefit will result unless a 2-inch coat of sand is applied. The sand benefits the bog by covering the injured runners, giving them an opportunity to throw out new roots, and by making conditions unsuitable for the development of another generation of the girdlers. If the coat of sand is sufficiently thick it will prevent the emergence of the girdler moths from their cocoons. No method of control by spraying or by the use of repellents has been developed.

CRANBERRY TOADBUG.[1]

One of the newer pests to be brought to the attention of cranberry growers is the cranberry toadbug, which first made itself of prime importance on some of the Long Island bogs and at about the same time appeared in New Jersey. The Massachusetts and Wisconsin bogs appear not to have been troubled, at least not to a serious extent, by this insect. The bugs rarely are found on any other plants in the neighborhood of the bogs and cranberry seems to be the only host which is injured in a large way.

Character of Injury.

The insect gets its food by sucking the juices of the plant through a long beak, and on cranberry the beak is inserted in the woody stems and apparently never in the foliage. Feeding on the old wood causes a dwarfing of the fruit on the branches beyond, and when a bug takes sap from the new wood the fruit will shrivel and death of the branch will result. The first signs of injury usually are noted in July, when the foliage assumes a reddish tinge, later becoming brown, and, as the injury progresses, many dead uprights bearing brown leaves will be found throughout the area.

Fig. 29. — Cranberry toadbug: Long-winged form of adult. Much enlarged.

Description and Seasonal History.

The adult bug, which is about three-sixteenths of an inch in length, is found in several forms, some of which are black, with short wings (fig. 28); some brown, with short wings; and some usually black but occasionally brown, with long wings

[1] *Phylloscelis atra* Germar.

FIG. 30.—Cranberry toadbug: Immature toadbug, or nymph. Much enlarged.

(fig. 29). The long-winged forms migrate in the fall, but by far the majority of the bugs have short elytra and abortive wings and remain on the bog. The bugs, both adult and nymph (fig. 30), are strong jumpers and move so quickly that seldom can they be located a second time. Eggs are laid during September and October, and in the operation of depositing them one is held at the tip of the abdomen by the female while she coats the entire egg with fine particles of dirt and grains of sand, after which she moves away, allowing the egg to drag on the ground until it drops off. The eggs remain on the floor of the bog until the following summer, being able to withstand both fall and winter flowage. Hatching occurs in late June and July and for a few days in August. The nymphs secrete a cottony material which breaks away from their bodies and coats the uprights on which they are feeding. Such white-coated uprights are, as a rule, indicative of toadbugs, but a similar effect is sometimes produced by the cranberry vinehopper.[1] The nymphs molt five times and the cast skins, clinging to the uprights, may be mistaken for the bugs themselves. Adults first appear in August.

TREATMENT.

The few severe outbreaks which have been observed in New Jersey have died out of their own accord. Among the natural controls of the pest are an insect parasite that produces a black hump on the back of the nymph and a fungous disease that has the appearance of the white mold.

FLOODING.

If water is available for summer use, the bog should be flooded, preferably in cloudy weather, some time between August 1 and 15. Instances are on record where such flooding was practiced for 48 hours without injury to the berry crop. Weeds and grasses which project above the flowage should not be allowed to remain. A good wind will blow the bugs to the shore, where they may be killed with a spray of burning kerosene.

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[1] *Amphiscepa bivittata* Say.

SPRAYING.

Where water is not available for floating the bugs off, a method of spraying worked out on Long Island as reported in Bulletin No. 377 of the New York Agricultural Experiment Station, may be tried. Heavy growth of vines must be mowed at the usual season for cutting and the spray applied between August 1 and 15, using soap solution, 1 pound to 7 gallons, and applying it at the rate of 200 gallons per acre. Two applications should be given.

OTHER CRANBERRY STEM FEEDERS.

CRANBERRY VINEHOPPER.[1]

Perhaps the most frequently encountered of the lesser pests of the woody parts of the cranberry is the cranberry vinehopper, which almost invariably is found where the vines have been weakened by some other agency. Adult bugs (fig. 31) are usually green, rarely pink, with large wings, giving them a flat-sided appearance, and are about one-fourth of an inch in length. They appear in July and August, and in late summer deposit their eggs in slits made with a sawlike ovipositor in live, woody stems (fig. 32) and, as frequently, in dry, dead pieces of cranberry wood on the ground. The eggs survive winter flowage and hatch in late June, when a succession of whitish nymphs, or young, bearing cottony secretions of wax appear. The nymphs are active jumpers, and the adults have the power of flying as well as jumping. Food is obtained by sucking the juices from uprights and runners.

The bugs could be removed by flooding in late July, but as a general rule they will need no treatment and will not infest a bog in large numbers if the vines are kept in a healthy, productive condition.

FIG. 31.—Cranberry vinehopper: Adults on cranberry stem. Considerably enlarged.

[1] *Amphiscepa bivittata* Say.

CRANBERRY SPITTLE INSECT.[1]

Records of the last few years in New Jersey show that the cranberry spittle insect is of more consequence on blueberry than on cranberry. From time to time, however, it has been brought to the attention of growers in Massachusetts and Wisconsin as a sucking insect of the vine. The masses of spittle which cover the nymph serve as a means of identifying this feeder, and it has been rarely if ever of sufficient importance to warrant the application of remedial measures.

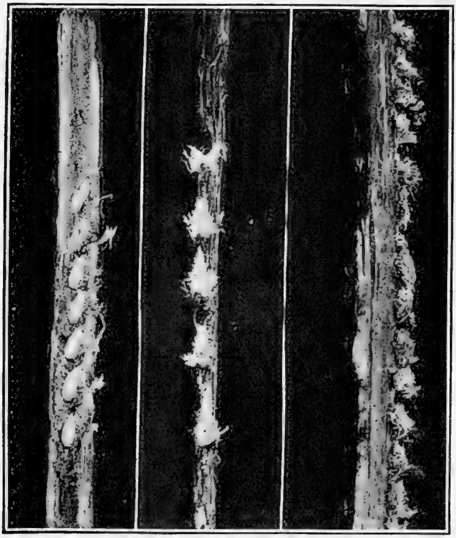

FIG. 32.—Cranberry vinehopper: Injury to cranberry stem by oviposition of adults, and the eggs in position in the stem. Much enlarged.

A MEALYBUG.[2]

Where the vines have been injured recently by the cranberry girdler there will be found frequently masses of white, cottony material (fig. 33) along the injured portions of the runners. On closer inspection this cottony material will be seen to cover the backs of the mealybugs, and in some cases their eggs or young. The bugs live by sucking sap from the vines, and it appears that conditions are more suitable for obtaining food where the vines have been gnawed by the girdlers. Vines in healthy condition appear not to be infested to any great extent by mealybugs.

SCALE INSECTS.

In recent years some of the scale insects have proved decidedly injurious to cranberry vines, notably the Putnam scale,[3] on Long Island, and the oyster-shell scale,[4] in Massachusetts, although in the latter case the scale apparently is able to maintain itself only on dry bogs.

[1] *Clastoptera proteus* Fitch.
[2] *Pseudococcus adonidum* L.
[3] *Aspidiotus ancylus* Putnam.
[4] *Lepidosaphes ulmi* L.

The Putnam scale is a formidable enemy, attacking not only the woody parts but also the leaves and fruit. Badly encrusted vines become very red of foliage and may be detected from a considerable distance. Infestation is likely to occur in areas, dotted here and there over the bog, from 2 or 3 feet in diameter to those comprising several square rods. Infested fruit becomes unsuitable for marketing and infested vines bear dwarfed fruit or are killed outright.

The use of water as a control for the Putnam scale seems to be barren of results, for the scales in the immature form hibernate beneath the winter flowage, and bogs that frequently are reflowed continue to be infested by them. They are difficult to reach by spraying, not only because the foliage prevents the spray from wetting them thoroughly, but also because many of the scales settle on the runners buried in the trash. Mowing the infested vines in the early spring, removing and burning the cut vines, and spraying the area with pure kerosene may prove to be an effective treatment Kerosene also may be used on the vines about the middle of August with fair impunity to the foliage but with damage to the fruit. This spray should be applied as a fine mist and used with care. Both lime-sulphur and a commercial preparation of soluble oil have proved harmful to dormant vines when used at the proper dilution for scale-killing. A fungous parasite[1] seems to be doing good work on certain bogs in destroying scales.

ROOT-ATTACKING INSECTS.

CRANBERRY ROOTWORM.[2]

Insects whose feeding on the roots of cranberry is of much consequence appear to be few, but of these the cranberry rootworm is probably the most injurious. Undoubtedly this has been long a pest of cranberry, but its discovery in that connection was not made until recently in New Jersey. The beetle has been found lately on a Long Island bog and the pest has been discovered on cranberry in Massachusetts.

FIG. 33.—Mealybug, *Pseudococcus adonidum:* Colony of mealybugs on cranberry runner. Much enlarged.

[1] *Sphaerostilbe coccophila* (Des.) Tul.

[2] *Rhabdopterus picipes* Oliv.

Although widely distributed throughout the United States, it appears not to have attained any importance economically until its root-feeding habit on cranberry was made known. Myrtle, wild grape, and basswood were its most frequently mentioned hosts, but to these should now be added the roots, foliage, and fruit of cranberry, and the roots and foliage of swamp blueberry.

CHARACTER OF INJURY.

The feeding of the beetles on the foliage and fruit of the cranberry is of minor consequence, although it does afford an opportunity

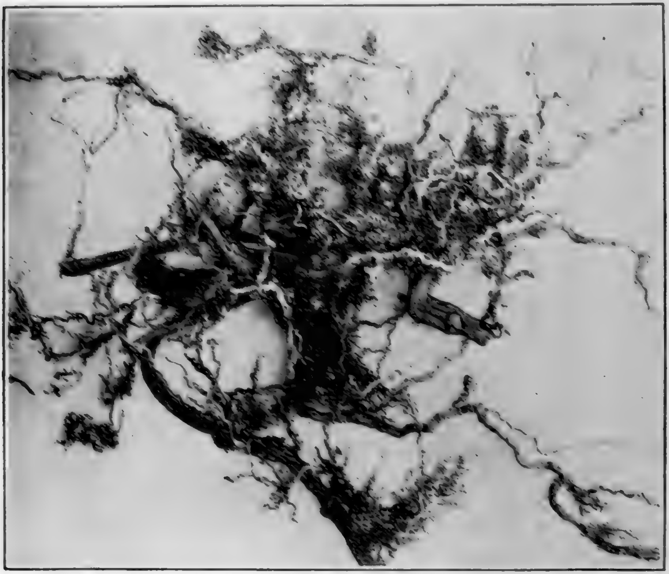

FIG. 34.—Cranberry rootworm: Injury to roots by the larvæ, or grubs.

of control by spraying with an arsenical. On the other hand, the worms, or grubs, which live in the soil beneath the vines, devour the fine roots and eat the bark of the large roots and runners, particularly where the latter come in contact with the ground. (Fig. 34.) This insect's feeding habits differ from those of the girdler in that it does its work beneath the surface of the ground, whereas the girdler feeds above the surface, concealed in the layer of trash which covers the runners.

Vines growing on sandy land suffer most, although severe infestations have been found on muck bottoms.

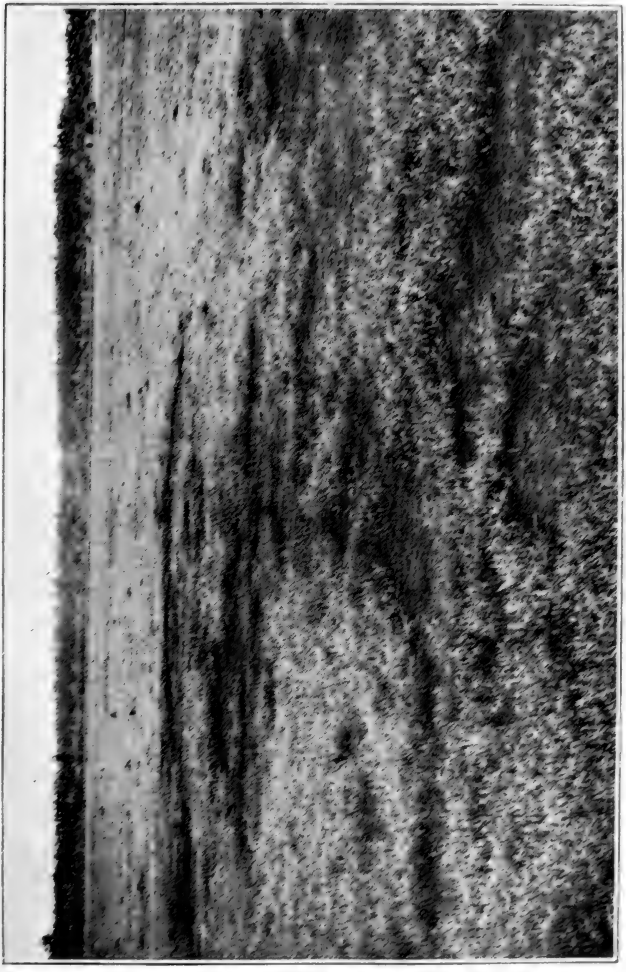

FIG. 33.—Cranberry rootworm. Cranberry marsh showing in the foreground patches of vines killed by the larvae.

Rootworm injury is first indicated by the reddish color of the foliage in late summer, followed by death of the vines and scattering

Fig. 36.—Cranberry rootworm: Larva, or grub. Much enlarged.

of the leaves. Such conditions are seldom of large area, usually being confined to spots ranging in area from one to several square rods along the high margins or on relatively high and sandy areas in the interior of the bogs. (Fig. 35.)

Description and Seasonal History.

HIBERNATION.

Hibernation occurs in the grub stage, from 1 to 10 inches deep in the bog soil, and is accomplished safely even on winter-flowed bogs. The grubs lie in their earthen cells until after the flowage is drawn off in the spring, when the more deeply buried ones move closer to the surface and all transform to pupæ, soon after which the emergence of the beetles takes place. The holes which the beetles leave in the soil may be seen easily on hard, sandy bottoms where there is little trash.

THE LARVA.

Most of the life of the rootworm, or about 10½ months on an average, is spent in the larval stage. Grubs may be found, however, at any season, because each year a few fail to complete their growth and therefore spend two winters in the ground.

The full-grown larva (fig. 36) is about five-sixteenths of an inch long, whitish, with brown head, and usually lies in a curved position.

Hatching of the yellow eggs begins in mid-July and the grubs then commence their root feeding, which lasts until early October, when hibernation begins.

THE PUPA.

Transformation from grub to pupa takes place in late May and early June, the time depending upon the date of removing the winter flowage; late holding of the flowage acts as a delay of pupation. Pupæ usually are found in the surface inch of soil and the stage lasts about 2 weeks. The pupa (fig. 37) is white and slightly shorter than a full-grown larva.

THE BEETLE.

Emergence of the beetles from the soil begins about mid-June and is at its height a few days later. In a cage placed over a badly injured area of vines an average of 20 beetles emerged to the square foot. During the day they are not found so readily as at night, when with a sweep-net 40 to 50 may be caught in four or five sweeps.

The beetle (fig. 38) measures slightly less than one-fourth inch and is shining mahogany brown. The usual duration of life is 1 month to 6 weeks, and during this time the eggs are laid singly, or in masses of as many as 50, just beneath the surface of the soil or on litter under the vines.

FIG. 37. — Cranberry rootworm: Pupa. Much enlarged.

TREATMENT.

Flooding the bog to control this insect is of little avail unless it be done when the beetles are feeding on the foliage in the latter part of June and early July. Since this time is also the beginning of the blooming period, a good deal of injury would result to the crop by reflowing, and such treatment can not be recommended unless it is desired to rest the bog by destroying the bloom. During the larval and pupal stages the rootworm can survive prolonged reflowing, and no dependence can be placed upon spring or fall reflows to exterminate it or even lessen its numbers appreciably.

Invigorating the vine growth by sanding on muck bottom and applying commercial fertilizer on sandy bottom promises good results in sustaining the vine growth, but should be accompanied by spraying, for which purpose one of the arsenicals may be used. Arsenate of lead is a satisfactory insecticide and should be applied at the rate of 3 pounds of the paste, or half that amount of the powder, to 50 gallons of water. Burning of the foliage has not been noted where 2 pounds of fish-oil soap have been included. The arsenical also may be used in combination with the Bordeaux and soap spray. At least two applications should be made, one about June 25 and the other as soon as the bloom has fallen.

FIG. 38.—Cranberry rootworm: Adult, or beetle. Much enlarged.

Carbon disulphid injected into the soil was found unsatisfactory and very expensive in an effort made to kill the larvæ.

WHITE GRUBS.[1]

The large root-feeding white grubs are found occasionally in cranberry bogs, but rarely are of much importance. The specific injury results from the feeding of the grubs on the fine roots of the vines, these being cut off completely, so that the vines with a thin layer of turf may be easily lifted and rolled back like a rug. The grubs then will be found at the surface or very near the surface of the exposed ground.

Fall reflowing for a period of 10 days, from October 25 to November 4, did not kill grubs in the soil. and they hibernate with safety on winter-flowed bogs. For small infestations of a few square rods, it seems best to "turf off" the infested area, which will be defined closely by the dead vines, and to reset with new vines.

Should a large area be infested and the destruction of the bog be threatened, it is probable that holding the winter flowage until July 15 would rid the bog of grubs.

[1] Particularly *Phytalus georgianus* Horn., *Dyscinctus trachypygus* Burm. and *Lachnosterna grandis* Sm.

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UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

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NO ONE METHOD for the control of the common mealybug can be recommended under all conditions. The remedy or remedies to be used will depend upon whether the trees are in house lots or orchards, whether few or many, and the infestation light or severe. In the case of severe infestation it will depend also upon the kind of fruit. This insect infests oranges of all varieties, grapefruit, lemons, and all other kinds of citrus fruit grown in California, causing deformity, weakening and dropping of much immature fruit, and the discoloration and weakening of the rind of the fruit maturing.

This bulletin discusses the three remedies which have been widely used; namely, fumigation, spraying, and the artificial spread of insect enemies, points out the sphere of usefulness of each method, and shows, on pages 14–15, how they may be combined so as to secure complete control.

An important part of the procedure recommended is the banding of trees with a mixture consisting of sulphur and a sticky material used to protect trees from insects. This keeps off the Argentine ant and other ants which attend and foster the mealybug and hinder or prevent the good work of insect enemies which otherwise might hold it in check. The method of preparing the mixture and applying the bands is described on pages 12–14.

Where the insect enemies are few or absent, or where they are themselves heavily parasitized, the trees should be sprayed or fumigated, and colonies of effective enemies should be introduced.

THE COMMON MEALYBUG[1] AND ITS CONTROL IN CALIFORNIA.

CONTENTS.

FAILURE of control methods against the common mealybug in California, together with its continued spread and the recent severe outbreak at Uplands, Cal., of a previously unknown species,[2] has caused mealybugs to be probably the most feared insect pests of citrus fruits in southern California to-day. The common mealybug is reported as destructive in Los Angeles, Orange, Santa Barbara, San Diego, and Ventura Counties. Fortunately, however, only a small percentage of the citrus acreage in these counties is now infested by this insect.

The common mealybug is of world-wide distribution and omnivorous habits. It appears first to have been reported in California as an orchard pest near Los Angeles more than 30 years ago, and subsequently came to notice in Paradise Valley, San Diego County. Its sporadic outbreaks continued to be of mere local concern until an extensive and severe infestation appeared in Ventura County in 1907-8, simultaneously with new but lesser areas of infestation in Los Angeles, San Diego, and Orange Counties.

NATURE OF INJURY AND HOST FRUITS PREFERRED.

A severe infestation of the common mealybug is well illustrated in figure 1 and in the illustration on the title-page. Immature fruit may be deformed or may become so weakened that it drops. Maturing fruit is frequently discolored, resulting in a high percentage of culls or fruit of low grade. The cottony secretion covering the egg masses is unsightly, and the sooty mold which develops in the honeydew exudations necessitates washing the fruit. Abnormal decay

[1] *Pseudococcus citri* Risso. [2] *Pseudococcus citrophilus* Clausen.

FIG. 1.—Lemon infested with the common mealybug.

usually follows the washing of this rind-weakened fruit. A severe infestation may result in partial or even complete defoliation of the trees. The lemon, grapefruit, and navel orange are preferred host fruits, although other varieties may be attacked severely.

CHARACTERISTICS AND LIFE HISTORY.

An idea of the superficial appearance of the common mealybug may be obtained from figure 2. The body of the insect is covered with a white waxy secretion, which is most pronounced in a bordering fringe of short filaments. The female retains the same general appearance through all stages of development from larva to adult. The male in its early stages is very similar to the female, but about four weeks after hatching it forms a cocoon, and from this it emerges, from 10 days to two weeks later, as a very small and delicate, light olive-brown, winged, gnatlike adult. Reproduction takes place from eggs deposited in a cottony sac secreted by the mature female. The number deposited depends on the size of the insect and varies from less than a hundred to more than a thousand, the average production of a female mealybug on green fruit being between 300 and 600 eggs. The length of a single generation on orange trees under the climatic conditions of Pasadena, Cal., during 1914–1916, varied from a minimum of 36 days during the summer to approximately six months during the winter. There are three more or less distinct generations a year on the citrus trees of southern California.

As a rule the infestations in the late winter and spring are so light as to escape notice, but later the crowding of the young insects on the small fruit, followed by the production of egg sacs in early summer, readily reveals the presence of the pest, and the maximum infestation and injury usually come in the early autumn with the second generation of mealybugs.

CONTROL OF THE MEALYBUG.

Three methods of control—fumigation, spraying, and the colonization of natural enemies—have played an important part in combating the mealybug on citrus trees and have been esteemed variously as the most promising. The studies carried on in southern California by this department indicate that no one of these control methods is applicable or preferable under all conditions of infestation, but by proper combination of these methods, and with the addition of banding to exclude ants, satisfactory control may be accomplished.

FUMIGATION.

Fumigation with hydrocyanic-acid gas as generally practiced for the black and red scales is a failure against mealybugs. No instance has been observed where the usual commercial treatment of an infested orchard with this gas has controlled this pest. Although records taken within a few weeks after fumigation have shown a reduction of the mealybug, such reduction was found invariably to be due largely to the action of natural agencies and doubtless would have occurred even though the trees had not been treated—a consideration seldom taken into account by the orchardist or commercial operator.

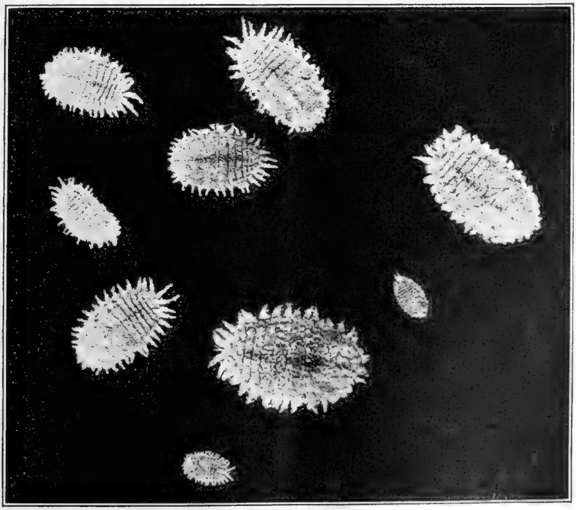

Fig. 2.—A group of common mealybugs. Enlarged about 9 times.

Table I sets forth the general results of experiments made to test the value of fumigation. The work was performed during the years from 1909 to 1917, under the climatic conditions normal to orchard fumigation in southern California.

TABLE I.—*Results of fumigation with hydrocyanic-acid gas against the common mealybug.*

A. 8-OUNCE U. S. ARMY DUCK TENT.

SINGLE CHARGE.

Dosage schedule.	Exposure.	Results.
No. 1[1]	1 hour	Small percentage killed. Commercially ineffective.
Two and three times No. 1.	do	85 to 95 per cent killed.

REPEATED CHARGE UNDER SAME TENT.

First charge.		Second charge.		Results.
Dosage schedule.	Exposure.	Dosage schedule.	Exposure.	
No. 1	30 minutes	No. 1	30 minutes	Small percentage living.
One and one-half times No. 1.	do	No. 1	1 hour	99 per cent killed.
No, 1	1 hour	No. 1	do	Do.

B. GAS-TIGHT TENT.

Sodium cyanid per 100 cubic feet.	Exposure.	Results.
1 ounce	1 hour	Sometimes a few living; usually all killed.
$1\frac{1}{4}$ ounces	do	All killed.

C. GAS-TIGHT BOX OF 100 CUBIC FEET CAPACITY.

$\frac{3}{4}$ ounce	45 minutes	A number living.
$\frac{3}{4}$ ounce	1 hour	A few living.
$\frac{3}{4}$ ounce	2 hours	Sometimes a few living.
$\frac{3}{4}$ ounce	4 hours	All killed.
1 ounce	45 minutes	Usually a few living.
1 ounce	1 hour	All killed.

[1] This schedule is given on page 34 of Bulletin No. 90 of the Bureau of Entomology, U. S. Department of Agriculture.

These results show the ineffectiveness of single-dosage fumigations under army duck tents, even where excessive dosages are used. Repeated charges give better results but can not be recommended except in the case of a limited number of trees where other control measures are not readily available, or where cost and possible injury are secondary to immediate control. Since 8-ounce United States Army duck retains hydrocyanic-acid gas better than any other cloth of which fumigation tents are constructed at present, results equally poor in comparison with those tabulated are to be expected under drill or double-filled duck covers.

Treatment under gas-tight tents is eminently successful from the standpoint of general control, it being possible to secure complete eradication on a small number of trees, and such treatment would be recommended in preference to any other means of artificial control but for the fact that no gas-tight tenting material practical for commercial usage is known at present. It is to be hoped and expected that a suitable gas-tight cloth will be forthcoming in the future. The dosage should be 1 ounce of sodium cyanid to each 100 cubic feet of space beneath the tented tree; for eradication, $1\frac{1}{4}$ ounces.

Citrus trees in dormant condition during the winter months will withstand safely a dosage as high as $1\frac{1}{4}$ ounces of sodium cyanid to 100 cubic feet of space under gas-tight covers. Heavy, repeated dosages under ordinary commercial tents have been used at this time with little damage to the trees. It is unsafe, however, to apply such concentrated gas to orange or grapefruit trees during the growing season.

Eradication of the mealybug can be effected in a gas-tight box or room with a dosage rate of 1 ounce of sodium cyanid to each 100 cubic feet of space.

SPRAYING.

RECOMMENDED SPRAY FORMULAS.

More than 100 different sprays have been tried against the mealybug, including insecticides formerly used and others developed during this investigation. Several preparations, including the resin wash and a $2\frac{1}{2}$ per cent paraffin-oil emulsion, have given fairly effective results; but two new sprays, cresolated distillate emulsion and soap-powder emulsion, are recommended as best measuring up to orchard requirements in mealybug control. The formulas for the preparation of these sprays are given below.

CRESOLATED DISTILLATE EMULSION.

Distillate (28° Baumé)	gallons	$2\frac{3}{4}$
Liquor cresolis compositus, U. S. P.	quarts	$1\frac{3}{4}$
Liquid fish-oil soap	quart	1
Soap powder (sodium carbonate 40–60 per cent, caustic soda 40–60 per cent)	pounds	3
Water to make	gallons	100

Preparation.—When the bottom of the spray tank is covered with water, start the agitator and sift in the finely ground soap powder, which dissolves while the tank is filling. Prepare the stock by first measuring the distillate, then pour the liquor cresolis compositus into the distillate and stir. Pour into the liquid soap twice as much of the foregoing mixture as of the soap and beat with a paddle until of uniform consistency. Then add remainder of mixture and stir thoroughly, after which the preparation is ready to be poured into the spray tank.

This spray has been used with success for more than a year and is recommended as the preferred insecticide for mealybugs. It has been applied to a very large variety of plants during the winter season without injury. Oranges and lemons are treated safely, though grapefruit has been known to be stained slightly. The grade of distillate is very important, and only that of a gravity approximating 28° Baumé should be purchased. This is an untreated black oil, very distinct from the stove distillate (32°–34° Baumé), which is commonly used for spraying. The cost of cresolated distillate emulsion is about $1\frac{1}{2}$ cents a gallon.

SOAP-POWDER EMULSION.

Distillate emulsion[1]	gallons	5
Soap powder	pounds	10
Water to make	gallons	100

Preparation.—When the bottom of the spray tank is covered with water, start agitator and sift in the finely ground soap powder. The distillate emulsion is added when the tank is almost filled.

Soap-powder emulsion is effective against the mealybug as well as against citrus scales. It is more injurious to the foliage than cresolated emulsion, however, and may cause moderate or even severe dropping of the leaves unless applied under favorable climatic conditions. (See "Season for spraying," p. 9.) The cost is about $\frac{3}{4}$ cent a gallon.

HOW TO SPRAY A TREE.

Trees first should be pruned of all dead wood and opened up so as to allow the ready use of the nozzle on the inside. In spraying for mealybug control the results accomplished are quite as dependent upon the method of application as upon the insecticidal properties of the material used. The upper, or dorsal, surface of the mealybug is tough and resistant to most commercially usable dips and sprays, the place of greatest vulnerability appearing to be a series of tubes which lie beneath the fringe of wax. This protective fringe, which is very resistant to most insecticides, must be removed by the spray to insure quick destruction of the insect; and to effect this removal careful treatment with a driving spray is required.

A power machine capable of maintaining 200 to 250 pounds pressure should be used. A very satisfactory type of nozzle is shown

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[1] Formula for distillate emulsion:

Distillate (28° Baumé)	gallons	20
Liquid fish-oil soap	do	4
Hot water	do	16

Pour hot water into spray tank. Start agitator, then add soap. Next slowly pour in distillate. Pump back into itself through nozzle for 20 minutes, after which pump through fine nozzle into storage tank. This emulsion keeps indefinitely.

in figure 3. The rods for spraying the inside and lower parts of the trees should not exceed 6 feet in length.

Mealybug infestation is confined in large part to the fruit, especially that toward the inside of the tree. It is recommended that the inside of the tree be sprayed first, starting at the lower part and moving upward, and then finishing over the outside of the tree. Especial effort should be made to spray the top of the tree, where the insects are most likely to escape treatment. Trees more than 10 feet in height should have their tops sprayed from a platform on the sprayer or from a light tripod ladder which can be carried from tree to tree. The nozzle should be moved rapidly about the tree, the spray being directed against both sides of the leaves, against the

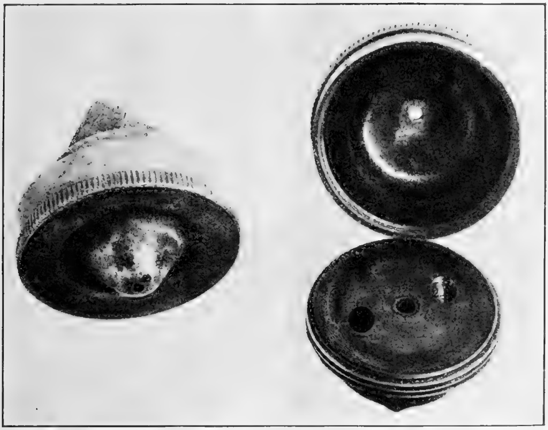

FIG. 3.—A type of nozzle well adapted to mealybug spraying.

fruit from at least two directions, and in all crevices which may harbor mealybugs. Thoroughly to spray a citrus tree 10 to 15 years old usually requires fully 20 gallons of material.

SEASON FOR SPRAYING.

Insecticidal sprays of the strength required to destroy the common mealybug may be applied safely to citrus trees in California only during the cool months of the year, when the fruit is either maturing or has been picked. This season generally extends from November to April, though the months of greatest plant resistance to sprays are December, January, and February. It is unsafe to apply the insecticidal sprays advocated in this bulletin when the temperature is above

80° F. or during the summer when the trees are laden with immature fruit. Should it appear advisable to employ a spray during the summer, water under pressure should be used, as this can be applied safely, even when the highest summer temperatures prevail.

WATER SPRAYING.

An increasing number of growers are using successfully water under pressure so as to dislodge the mealybugs forcibly from citrus trees. This method of control was demonstrated in several orchards during the years 1915 and 1916, with varying degrees of success. Control of mealybugs by water spraying is practicable in the case of all citrus fruits excepting possibly the navel orange, but its success depends on thorough and repeated applications. Especially is this true of the navel orange, which requires such a large number of applications that the method is generally impractical in extensive and severe infestations.

Water has one important advantage over all other sprays in that it may be used with safety in unlimited quantities at any time of the year, thus affording a means of combating mealybugs during the summer months when practically all insecticides of value are too injurious to fruit and foilage to justify their application.

Several matters have a very important bearing on the successful commercial use of water spraying. In orchards the cost can be reduced materially by installing a system of piping, the power being derived from the water main, a stationary pump, or a power sprayer. The piping should be of a diameter to give ample force. The best type of nozzle allows an uninterrupted flow through an aperture not larger than one-fourth of an inch. The writers devised a very satisfactory direct-discharge nozzle having a rectangular opening 6 by 2 millimeters and capable of delivering 6 to 7 gallons a minute under 100 pounds pressure. The common garden type or a $\frac{1}{4}$-inch fire nozzle, however, will serve the purpose. Nozzles with small openings, as those of the Bordeaux type, are unsuitable for water spraying, as the stream of water will strip the leaves and cut off fruit. The tops of the trees should be sprayed from a ladder. Twenty to thirty minutes are required for spraying thoroughly a tree 10 to 15 years old.

CONTROL BY NATURAL ENEMIES.[1]

No important citrus insect pest in California seems to be attacked by more natural enemies than the mealybug, and efficient control of

[1] The more effective enemies of this species, including both predators and parasites, given in the order of their importance, are: *Sympherobius barberi* Banks, *S. californicus* Banks, *Hyperaspis lateralis* Muls., *Cryptolaemus montrouzieri* Muls., *Chrysopa californica* Banks, *Leucopis bella* Loew, and *Paraleptomastix abnormis* Girault.

the mealybug by these natural enemies is often noted. For example, one severely infested orchard was observed to be cleaned in less than two months to an extent satisfactory in commercial control by two species of predatory brown lacewing flies.[1] Other groves have enjoyed similar respite from mealybug injury through the activity of these brown lacewings, aided by one or the other of two species of ladybird beetles.[2] Undeserved credit is often given to insecticides, in the case of orchards that have contained these natural enemies in large numbers at the time of spraying or fumigation, while in fact the mealybugs have been destroyed by these predatory enemies unobserved by the orchardist or operator. The natural enemies are most efficacious during the autumn and early spring.

RELATION OF ANTS TO NATURAL CONTROL.

Since the mealybug is beset with so many efficient natural enemies, it has been the cause of considerable wonder that the pest is not more generally kept in check. The infestation may be reduced during the autumn or spring to a point bordering on control or even eradication, yet it is a matter of common observation in some localities that in spite of these conditions one severe infestation follows another year after year. This failure of the natural enemies to hold the mealybug in check throughout the year has been found to be due mainly to the presence on the trees of large colonies of ants, the Argentine ant [3] being the greatest offender. The experimental work reported in this bulletin has been confined to the Argentine ant, which has been observed to carry living mealybugs, to destroy and carry off the larvæ and eggs of natural enemies, to interfere with the free movement about the tree of certain beneficial insects, and by their constant attendance upon the mealybugs to prevent normal egg laying and feeding of the adult parasites and predatory enemies.

Remarkable results have been secured by keeping the Argentine ant off of trees infested with mealybugs by banding with a sticky mixture. In Los Angeles County during 1915 and 1916 trees that when first freed from ants were infested severely with the mealybug became commercially clean, without exception, within a period of six weeks to three months. The mealybug remained under control throughout the year or during the period of the experiments, while trees in adjacent check rows only a few feet away continued to be severely infested. The natural enemies responsible for this control were the two brown lacewings and a ladybird beetle.[4]

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[1] *Sympherobius barberi* Banks and *Sympherobius californicus* Banks.
[2] Either *Hyperaspis lateralis* Muls. or *Cryptolaemus montrouzieri* Muls.
[3] *Iridomyrmex humilis* Mayr.
[4] *Hyperaspis lateralis* Muls.

An experiment typical of many others is given in Table II.

TABLE II.—*Relation of the Argentine ant to the natural control of the mealybug. Experiments at Sierra Madre, Cal., July to October, 1916. [Percentage of fruit infested with the mealybug on each tree. Twenty orange trees to each test.]*

I. NO INSECTICIDAL TREATMENT.

Tree No.	1	2	3	4	5	6	7	8	9	10
Infestation at start of test, July 25. All trees frequented with ants:										
a. Check row, unbanded	100	100	94	80	34	90	100	100	91	100
b. Banded	92	96	92	86	100	73	82	75	93	100
Six weeks after start, Sept. 6:										
a. Check row, unbanded	100	92	80	91	73	100	100	86	90	100
b. Banded	1	3	2	1	15	1	2	1	......	24
Eleven weeks after start, Oct. 11:										
a. Check row, unbanded	100	82	45	50	32	61	96	76	42	86
b. Banded [1]	0	1	0	0	1	0	1	0	0	1

[1] Only 8 infested fruit on entire 10 banded trees.

II. TREES SPRAYED WITH WATER ON JULY 25.

Condition before water spraying, July 24:										
a. Unbanded	94	100	97	100	100	100	85	100	100	100
b. Banded	30	98	100	90	55	93	89	100	100	86
Six weeks after start, Sept. 6:										
a. Unbanded	100	95	94	99	100	98	100	59	100	94
b. Banded	2	1	9	2	1	4	14	1	3	3
Eleven weeks after start, Oct. 11:										
a. Unbanded	90	93	92	90	94	100	100	20	100	100
b. Banded	1	0	1	0	0	0	1	0	0	0

HOW TO KEEP ANTS OFF OF TREES.

To free trees of ants the ideal procedure would be to eradicate these insects from the area affected. The writers have not carried on any such tests, but the published results of work carried on by the Department of Agriculture against the Argentine ant[1] would indicate the feasibility of freeing orchards of this pest.

The procedure followed with noteworthy success in municipal control work was the distribution throughout the affected area of a poisoned sirup in a suitable container. A paraffined paper bag, with perforations for the passing of ants, containing about a gill of sirup, was used as a container for nailing to trees.

The sirup is made as follows:

Granulated sugar	pounds	15
Water	pints	7
Tartaric acid (crystallized)	ounce	¼
Boil for 30 minutes. Allow to cool.		
Dissolve sodium arsenite (C. P.)	ounce	¾
In hot water	pint	1
Cool. Add poison solution to sirup and stir well. Add to the poisoned sirup:		
Honey	pounds	1½
Mix thoroughly.		

[1] Barber, E. R. The Argentine Ant: Distribution and Control in the United States. U. S. Dept. Agr. Bul. 377. 23 p., 4 fig. 1916. Newell, Wilmon, and Barber, T. C. The Argentine Ant. U. S. Dept. Agr. Bur. Ent. Bul. 122. 98 p., 13 pl., 13 fig. 1913.

A number of experiments with banding in orchards infested with the Argentine ant have proved the practicability of this method of keeping trees free of ants during their active season, and this method of control is recommended (see fig. 4) as the most effective one tried. Before the band is applied the tree should be pruned so that the lowest branch is fully a foot above the ground, and all rubbish should be removed from beneath the tree and the soil cultivated to destroy all grass and weeds. The only banding material which has given satisfaction is a mixture[2] made up as follows:

Finely powdered flowers of sulphur____________part by weight__	1
Commercial tree-banding sticky material______parts by weight__	6

The two ingredients are mixed together thoroughly with a wooden paddle until of a uniform color and consistency. That possible injury may be avoided, this is not applied directly to the bark, although direct application of the commercial sticky tree-banding material alone has never been noted in California to affect citrus trees seriously. First coat the trunk with a thin layer of paraffin and apply the mixture of sulphur and sticky tree-banding material over this. Paraffin that has a high melting point is preferable, and it is applied with a brush while melted. It hardens almost immediately, after which the mixture just referred to can be applied in a band about 5 inches wide and almost one-fourth inch thick. A single application of this material has kept trees free of ants for several months during warm weather.

FIG. 4.—Keeping ants off citrus trees. A 5-inch band of sulphur and commercial sticky tree-banding material over a wider coating of paraffin.

[2] Compounded by Mr. J. R. Horton of the Bureau of Entomology, U. S. Department of Agriculture. (See Horton, J. R. Some weatherproof bands for use against ants. *In* Mo. Bul. Cal. State Com. Hort., v. 5, no. 11, p. 419–421. 1916.)

Ants that are on trees at the time of banding usually drop off within a day or two unless nests are in the trunk or branches. If nests are present, however, they should be destroyed by applying pyrethrum or some other ant powder, or with a fine spray of gasoline from a plumber's torch, or with cresolated emulsion applied with a 3-gallon compressed-air sprayer. This should be done early in the morning, while the ants are least active.

Inspection should be made weekly for the discovery of reinfested trees, the bands being renewed where necessary and the branches of the trees kept from coming in contact with weeds or the ground.

GENERAL RECOMMENDATIONS.

In view of the success secured in the foregoing experiments in controlling the mealybug by keeping ants off of the trees, the impression might be conveyed that banding alone is all that is necessary to keep orchards commercially free of this destructive pest. Under present conditions this would probably prove true in most cases; nevertheless, two important factors must be kept in mind when a general scheme of control for the common mealybug in southern California is under consideration: (1) The possible scarcity or absence of effective beneficial insects in the infested orchard and (2) heavy parasitism of the beneficial natural enemies themselves in some localities at certain seasons of the year. Control of the mealybug under either of these conditions could not be effected quickly except by spraying or other artificial control, unless it should be possible to introduce promptly large colonies of effective natural enemies.

General recommendations for control are given below, and it is believed that complete success will result if they are followed closely in all details. Frequent examinations to detect ant reinfestation must be made, and colonization of natural enemies, where not present already in noticeable numbers, is essential. The trees should be sprayed wherever the conditions demand it.

PROCEDURE RECOMMENDED FOR THE CONTROL OF THE COMMON MEALYBUG.

TREES IN ORCHARDS.

1. Where there are very few trees.
   - *a.* Prune heavily for spraying, with lowest branches at least 1 foot above ground.
   - *b.* Band trees with sulphur-sticky mixture and keep them free of ants.
   - *c.* Attempt eradication by spraying with cresolated emulsion or by fumigation under a gas-tight tent.
   - *d.* Inspect weekly. If living insects are present, respray or refumigate until they are eradicated.

2. Where there is a light general infestation.
   A. Where no trees are severely infested.
      1. Pick navel fruit, including all culls and off bloom, before March 1.
      2. Band trees with sulphur-sticky mixture, preferably in February or March. Free trees of ants.
      3. Introduce large colonies of the four most useful insect enemies,[1] if these are not present in noticeable numbers. This should be done preferably in March or April, but introduction can be continued throughout the season, if necessary.
      4. Inspect weekly for ant reinfestation.
      5. Spray with water during summer, if infestation becomes severe.
   B. Where there are a few severely infested trees in an orchard otherwise lightly infested.
      1. Such trees should have the infestation greatly reduced during the month of February, either by spraying with cresolated or soap-powder emulsion or by fumigation under a gas-tight tent. Afterwards they can be handled like the rest of the orchard, as explained in A above.
3. Where there is severe infestation.
   A. Treatment of navels, grapefruit, and lemons.
      1. *Navels and grapefruit.*—Pick all fruit, including culls and off bloom, before treatment. Leave culls and off bloom on the ground.
         Lemons.—Pick all marketable fruit before treatment.
      2. Prune heavily for spraying, with the lowest branches at least 1 foot above the ground.
      3. Following removal of fruit, spray with cresolated or soap-powder emulsion, or fumigate under a gas-tight tent, preferably in February.
      4, 5, 6, 7. The same as for *A* 2, 3, 4, and 5, respectively, in section 2.
   B. Treatment of Valencias.
      The procedure is the same as for navels, grapefruit, and lemons, except that the fruit is not picked, while the spraying should be done with cresolated distillate emulsion.

TREES IN HOUSE LOTS.

1. Pick all fruit during the winter.
2. Prune heavily and keep free from buildings, other plants, etc.
3. Fumigate with eradication dosage under gas-tight tent if available. Otherwise spray heavily with cresolated or soap-powder emulsion.
4. Band with sulphur-sticky mixture and keep free of ants.
5. Spray frequently with water if living insects continue on trees.

PREVENTING SPREAD THROUGH PICKING BOXES AND BY PICKERS.

The present localization of the common mealybug renders advisable the adoption of some means to prevent its spread to new regions through such controllable agencies as picking boxes and picking sacks. Picking boxes which have been known to carry fruit infested with the mealybug should be treated before use in uninfested

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[1] *Sympherobius californicus, S. barberi, Hyperaspis lateralis,* and *Cryptolaemus montrouzieri.*

orchards. Eradication of this insect on boxes is secured by fumigation in a gas-tight room with hydrocyanic-acid gas at the rate of 1 ounce of sodium cyanid to each 100 cubic feet of space, or with sulphur at the same strength.

Dipping picking sacks, gloves, and jumpers in gasoline for five minutes will destroy all insects and eggs. As the gasoline evaporates in a few minutes, the cloth or leather will be ready for use again before the next orchard is reached.

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TOBACCO HORNWORM INSECTICIDE

RECOMMENDATIONS FOR USE OF POWDERED ARSENATE OF LEAD IN DARK-TOBACCO DISTRICT

A. C. MORGAN

Entomologist, Southern Field Crop Insect Investigations

FARMERS' BULLETIN 867

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C. August, 1917

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FROM the time when tobacco was first cultivated in the dark-tobacco regions of Tennessee and Kentucky it has been necessary to combat the hornworms in order to produce profitable crops. For many years the practice of removing them from the plants by hand was followed. Later Paris green came into general use. This bulletin deals with the use of powdered arsenate of lead, which has been found to be preferable to Paris green in many respects. Full directions for its use under varying conditions are given.

TOBACCO HORNWORM INSECTICIDE:

RECOMMENDATIONS FOR USE OF POWDERED ARSENATE OF LEAD IN DARK-TOBACCO DISTRICT.

CONTENTS.

TOBACCO HORNWORMS[1] are the everpresent and most serious pests of tobacco in Tennessee and Kentucky. Without control measures no tobacco could be grown. When labor was cheap and plentiful, hand-worming as a means of control was fairly satisfactory, but with the increasing scarcity, cost, and inefficiency of hand labor this method had to be abandoned and the tobacco growers were forced to use an insecticide or cut down the acreage. About 20 years ago, when insecticides were first employed, Paris green was found to be the safest and most efficient. Nevertheless, there has always been serious objection to its use on account of the very frequent serious burning of tobacco, which reduced the value of the crop frequently as much as 5 per cent and occasionally by as much as from 10 to 25 per cent. To find a safe and efficient insecticide has been one of the main lines of investigation at one of the field laboratories of the United States Bureau of Entomology in Tennessee. As a result of the present investigation the diplumbic form of arsenate of lead was found to meet all requirements.

During the last three years tobacco growers in the "Black Patch" have used many tons of arsenate of lead upon tobacco, and from the reports of satisfaction received it is very evident that its use will be increased during 1917; accordingly, for the benefit of those who will use arsenate of lead for the first time, as well as for those who have begun its use recently, it has been thought advisable to set forth a comparison of results obtained by farmers in 1916 with both Paris green and arsenate of lead with the results obtained by agents of the bureau from arsenate of lead experiments, that tobacco growers may know, from actual records, what to expect in following the bureau recommendations.

[1] *Phlegethontius sexta* Joh. and *P. quinquemaculata* Haw.; order Lepidoptera, family Sphingidæ.

NOTE.—This bulletin supersedes Farmers' Bulletin 595.

ADVANTAGES IN THE USE OF ARSENATE OF LEAD.

Hand-worming, as has been stated, is impossible upon a large scale because of the scarcity of labor, its relatively high cost, and its general inefficiency. Under average conditions of infestation hand worming will cost at least $10 an acre, and even with this amount of labor, damage by worms can not be prevented entirely, for the most vigilant wormer will overlook many worms. On the other hand a thorough application of arsenate of lead will be effective for a period of at least 10 days following the application, and under favorable conditions will keep the tobacco clean for that period. The records at hand do not show that Paris green can be expected to exert satisfactory control for a period longer than from five to seven days. Arsenate of lead adheres to tobacco longer than does Paris green, and rarely does it cause any burning of the plant. The authentic cases of injury by arsenate of lead have been so few, and the attendant damage so slight as compared with that caused by Paris green, that the probability of damage is not considered by farmers who have used arsenate of lead long enough to become thoroughly familiar with its action.

In addition to its longer period of effectiveness and the greater safety to the plant, arsenate of lead is not now much more costly per application than is Paris green, and when the longer period of effectiveness is considered it is the more economical. This poison is also very much less irritating to the skin than is Paris green and, so far, there has been no complaint of its having produced sores upon workmen who applied it.

SOME EARLY TESTS OF ARSENATE OF LEAD IN COMPARISON WITH PARIS GREEN.

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. On the fifth day after the application, however, numbers of small worms were seen working 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 the worms for several days after the Paris green had lost its effect.

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

On August 21, 1911, arsenate of lead at the rate of $4\frac{3}{8}$ 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 $1\frac{3}{4}$ 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 rate of 5 pounds and 4 pounds per acre, respectively, and Paris green was applied to the check plat at the rate of $2\frac{1}{2}$ 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 $2\frac{1}{2}$-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 in 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, a total of $12\frac{1}{4}$ pounds being used, an average of a little more than 3 pounds per dosage. The first dosage, only $2\frac{1}{2}$ pounds, was too light, however, and it had to be repeated. Had the first dosage been at the rate of about 4 pounds per acre, undoubtedly two more dosages of about $3\frac{1}{2}$ 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 \$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.

COMPARISON OF RESULTS OBTAINED BY THE USE OF PARIS GREEN AND ARSENATE OF LEAD IN 1916 IN KENTUCKY AND TENNESSEE.

In the year 1916 records of the results obtained from dust applications of both Paris green and arsenate of lead, by farmers in several counties in Kentucky and Tennessee, were made to determine the relative efficiency of these two insecticides.

On 92 fields upon which they had applied Paris green at the average rate of 1.31 pounds per acre, 22.7 per cent of the worms were found dead 9 days after the application. On 108 fields upon which they had applied arsenate of lead at the average rate of 3.2 pounds per acre, 48.14 per cent of the worms were found dead 13 days after the application.

No better comment could be made upon the comparative insecticidal values of Paris green and arsenate of lead than the foregoing statement of results, particularly so when it is considered that the average dosage of Paris green was as large as could be applied with reasonable safety and that the dosage of arsenate of lead could have been doubled without causing any serious damage to the tobacco plants.

Although an examination of these fields 3 to 5 days after the applications undoubtedly would have shown that the hornworms were being killed in considerable numbers in many instances, yet it would have shown also that the fields were not being kept free of worms. The records show also that with a light dosage of arsenate of lead more than twice as many worms were being killed as with the usual dosage of Paris green.

Table 1 shows the average results of the best fourth of the field records mentioned above.

TABLE 1.—*Comparison of applications of Paris green and arsenate of lead made by farmers in Kentucky and Tennessee, using the best fourth of the records of each.*

Poison used.	Average number of days from application to examination.	Average dosage per acre.	Hornworms killed.	Number of fields recorded.
		Pounds.	*Per cent.*	
Paris green	$5\frac{4}{5}$	$1\frac{2}{5}$	47.1	23
Arsenate of lead	$4\frac{1}{3}$	$4\frac{4}{9}$	83.3	27

The foregoing comparison of the best results obtained by farmers brings out two facts very clearly: First, farmers, on the average, are not keeping tobacco free of hornworms in a satisfactory manner with Paris green; second, they are securing much better results with arsenate of lead than with Paris green.

Before discussing the dosage of arsenate of lead required under different conditions it will be well to compare the results obtained by farmers with arsenate of lead with results obtained through field applications made by agents of this bureau.

RESULTS OF FARMERS' APPLICATIONS OF ARSENATE OF LEAD VERSUS RESULTS OF APPLICATIONS MADE BY BUREAU AGENTS.

Table 2 compares the results obtained by agents of this bureau with results obtained by farmers upon the 27 fields recorded in Table 1.

TABLE 2.—*Comparison of the best fourth of farmers' applications of arsenate of lead with the best fourth of the applications of the same insecticide made by agents of the bureau.*

Applied by—	Number of days from application to examination.	Average dosage per acre.	Hornworms killed.	Number of fields recorded.
		Pounds.	*Per cent.*	
Farmers	$4\frac{1}{3}$	$4\frac{4}{9}$	83.3	27
Bureau agents	$3\frac{3}{5}$	$5\frac{1}{10}$	88.6	25

The farmers' application of $4\frac{4}{9}$ pounds per acre killed 5 per cent less worms in $4\frac{1}{3}$ days than were killed by the application of $5\frac{1}{10}$ pounds per acre by agents of the bureau in $3\frac{3}{5}$ days. Both dosages did good work, but there is considerable advantage in favor of the $5\frac{1}{10}$ pound dosage. Table 2 does not show a very great advantage in favor of the $5\frac{1}{10}$ pound dosage as compared with the dosage of $4\frac{4}{9}$ pounds, but something of the lasting effects of large dosages must be learned before a proper conclusion can be drawn. Table 3 shows the lasting results of a large dosage very plainly. The examinations of the experiments by agents of this bureau were made at periods varying from 8 to 15 days after the applications, and are compared with examinations made 9 to 12 days after applications by farmers. The average period between application and examination will be seen to be practically the same. The tobacco was full grown, promising an average yield of 800 pounds per acre.

TABLE 3.—*Results of examinations made at the expiration of an average of 10 days after applications of arsenate of lead made by agents of this bureau and by farmers.*

Applied by—	Average examination period.	Number of fields examined.	Average dosage.	Hornworms found dead.
	Days.		*Pounds.*	*Per cent.*
Agents	10.3	10	5.1	72.6
Farmers	10.0	16	4.0	31.0

The results in Table 3 show conclusively that a 4-pound dosage can not be expected to keep tobacco even approximately clean for a period of 10 days, and that a dosage of 5 pounds will kill a great many worms in 10 days, since the examinations of the 5-pound dosage showed nearly $2\frac{1}{2}$ times as many dead worms as in the case of the 4-pound dosage. It is very evident that large tobacco must be given at least a 5-pound dosage if it is to be kept reasonably free of worms for more than a few days.

DOSAGE OF ARSENATE OF LEAD REQUIRED.

The foregoing records were all taken from fields upon which only one dosage of lead arsenate was applied. The tobacco was practically full grown and, as a rule, was infested heavily with hornworms, many of which were half grown or larger; under such conditions a 5-pound dosage of arsenate of lead is absolutely necessary. It is better, however, not to rely upon one application to keep tobacco clean, for one good application can not be expected to do satisfactory work, under average conditions, for more than 10 days. Therefore, in seasons during which the moths deposit eggs in considerable numbers over a period much greater than 10 days, another dosage of an insecticide must be applied or the worms must be hand-picked.

AT LEAST TWO DOSAGES RECOMMENDED.

Under usual conditions in the "Black Patch" in Kentucky and Tennessee at least two dosages should be given. The size of the dosages must be governed by the size of the worms. If the worms are small and the tobacco is not more than half grown, a $3\frac{1}{2}$-pound dosage per acre, evenly applied, will be sufficient. This may be followed by a dosage of from $3\frac{1}{2}$ to 4 pounds when small worms again appear in any considerable numbers. If, on the other hand, worms are large at the time of the first application, not less than from 4 to $4\frac{1}{2}$ pounds per acre should be applied. If the tobacco is large, 5 pounds per acre should be used. The time and necessity for a second dosage must be determined by an examination of the fields at intervals of two or three days after the first application, and the size of the dosage should be governed by the size of the tobacco and number of worms.

Table 4 will furnish a good working basis for applications of arsenate of lead in most cases.

TABLE 4.—*A working basis for applications of powdered arsenate of lead for general use.*

Size of tobacco.	Size of worm.	Powdered arsenate of lead per acre.
		Pounds.
Half grown or less	Small	$3\frac{1}{2}$
Do	Large	4 to $4\frac{1}{2}$
Half grown to full grown	Small	4
Do	Large	4 to 5
Full grown	Small	4 to $4\frac{1}{2}$
Do	Large	5 to 6

HOW TO APPLY ARSENATE OF LEAD TO TOBACCO.

It is recommended that dry wood-ashes be mixed with arsenate of lead in order to make it dust evenly and to prevent its clogging in the gun. It is also recommended that a dust gun be obtained having a fan diameter of at least 8 inches. However, if a dust gun is secured having a fan diameter of at least 10 inches and a special device to prevent clogging just below the hopper where the insecticide is fed into the delivery pipe, the arsenate of lead may be applied without mixing it with a carrier.

It is important to use a powerful dust gun and to make a thorough and even application. Do not attempt to apply any dust poison during a strong breeze. Absolute calm is to be preferred and the best applications can be made only under that condition. Make dust applications early in the morning or late in the afternoon when the air is still or there is at most only a slight breeze. Thoroughness and evenness of application can not be emphasized too strongly, for an uneven application made in a strong breeze will leave enough live worms to damage the tobacco seriously.

WHEN TO APPLY ARSENATE OF LEAD.

The first application should be made when worms become too numerous to be kept off tobacco easily by the hand-picking that is usually done while hoeing, suckering, or topping. Many farmers make only one application, and that at a time when worms are numerous and many of them half grown or larger. It is better to make more than one application, the first one being applied as recommended. The time for repeating the application can be determined by the numbers of eggs and young worms appearing upon the tobacco. Worms should be killed during the first week after hatching, for during the second and third weeks they are much harder to kill and they will eat many times as much tobacco as is consumed during the first week.

GRADE OF ARSENATE OF LEAD THAT SHOULD BE USED.

Arsenate of lead may be divided, broadly, 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 arsenic oxid* (As_2O_5) *of 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.

COST OF ARSENATE OF LEAD.

In 1916 the grade of powdered arsenate of lead recommended for treating tobacco retailed at prices ranging from 20 to 30 cents per pound; very little, however, being sold for more than 25 cents per pound. By clubbing together farmers may find it possible to buy somewhat cheaper direct from the factory. At 25 cents per pound the first application of powdered arsenate of lead will cost from 87½ cents to $1 per acre, and at 1916 prices the 5-pound dosage recommended for large tobacco will cost $1.25. With Paris green, a 1½-pound dosage would cost from 60 to 80 cents, and a 2-pound dosage would cost from 80 cents to $1. At present, therefore, it is apparent that arsenate of lead is almost as cheap as Paris green, and when its greater lasting qualities are taken into consideration it is cheaper.

SUMMARY.

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

Arsenate of lead never seriously injures tobacco even under the most unfavorable conditions.

A dosage of Paris green large enough to be effective against hornworms can not be applied without grave danger of burning tobacco.

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

Arsenate of lead is safe and effective during rainy weather, whereas 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 to 5 pounds per acre. If applied as a spray, use from 3 to 4 pounds in 100 gallons of water.

To apply arsenate of lead in powdered form, without a carrier, use a dust gun having a fan diameter of at least 10 inches and a special device for preventing clogging of the delivery pipe. If a gun with such a device is not used, it will be necessary to mix the arsenate of lead thoroughly with equal parts of *dry* wood ashes.

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

Use only such brands of arsenate of lead as are guaranteed to contain at least 30 per cent of arsenic oxid, of which not more than 1 per cent is free, or water-soluble.

PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO INSECTS INJURIOUS TO TOBACCO.

AVAILABLE FOR FREE DISTRIBUTION.

Tobacco Budworm and its Control. (Farmers' Bulletin 819.)
Tobacco Beetle and How to Prevent Damage by It. (Farmers' Bulletin 846.)
Tobacco Splitworm. (Department Bulletin 59.)
Methods of Controlling Tobacco Insects. (Entomology Circular 123.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

So-called Tobacco Wireworm in Virginia. (Department Bulletin 78.) 1914. Price, 5 cents.

Tobacco Thrips and Remedies to Prevent "White Veins" in Wrapper Tobacco. (Entomology Circular 68.) 1906. Price, 5 cents.

Tobacco Thrips, a New and Destructive Enemy of Shade-grown Tobacco. (Entomology Bulletin 65.) 1907. Price, 5 cents.

Principal Insects Affecting Tobacco Plant. (Farmers' Bulletin 120.) 1900. Price, 5 cents.

HOW TO INCREASE THE POTATO CROP BY SPRAYING

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Colorado Potato Beetle and Its Larvæ, or "Slugs," Feeding

FARMERS' BULLETIN 868
UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology, L. O. Howard, Chief
and the Bureau of Plant Industry, W. A. Taylor, Chief

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IT IS ESTIMATED that the potato crop of the country is reduced each year more than 100,000,000 bushels as the result of injury by insects and diseases. If spraying were not practiced, this loss would be much greater, but even at the present time spraying is not practiced as widely or as thoroughly as it should be, and the present crisis should impel all growers to increase their crops by preventing these enormous losses.

This bulletin tells how to control the Colorado potato beetle and late-blight (the worst two enemies of the potato), blister beetles, flea-beetles, cutworms, and other caterpillars, leafhoppers, " aphis " or plant-lice, early-blight, and other foliage diseases.

For most of these insects and for the diseases discussed in this bulletin, spraying with Bordeaux mixture and arsenate of lead is recommended, but for leafhoppers and plant-lice, contact sprays, such as nicotine sulphate and emulsions, are the best. For blight, Bordeaux mixture is an efficient means of control. Directions for preparing and applying these sprays are given. Other methods of control described in this bulletin, such as jarring and driving, together with crop rotation and clean cultural methods, also help considerably in protecting the crop.

The best spraying outfits available should be procured.

HOW TO INCREASE THE POTATO CROP BY SPRAYING.

CONTENTS.

THE demand for an increased yield per acre in the potato crop has become urgent. In the year 1915 the average yield of potatoes in the United States was estimated at 96 bushels per acre. In the following year the estimated average yield decreased to about 80 bushels per acre.

Two of the causes of low crop yield are insects and diseases. It has been estimated that the total loss from potato diseases and insects in the United States frequently is as much as 100,000,000 bushels. In New York 20,000,000 bushels were lost to potato growers as a result of late-blight in 1912.

COLORADO POTATO BEETLE.[1]

Injury by the Colorado potato beetle is the work of both the "slugs" (young, or larvæ) and the beetles (adults). The beetles, after they pass the winter, appear usually at about the same time as the potato plants, lay their eggs, continue feeding, and frequently destroy small areas entirely, especially those grown for garden purposes. On larger areas the species, as a rule, is somewhat less injurious. When the larvæ begin to grow, they usually finish the work begun by the beetles, so that in a very short time, or by the time the larvæ are

[1] *Leptinotarsa decemlineata* Say.

NOTE.—The insects treated in this bulletin are all leaf-feeders. Some of those which feed in the stalks and tubers, viz, the potato stalk-weevil, the common stalk-borer, the potato tuber-moth, white grubs, and wireworms, also are very injurious in certain areas, but these are controlled by methods different from those used against the leaf-feeders, and they will be treated in a separate publication. The diseases treated herein are those affecting the foliage and are preventable, in the main, by spraying. Other potato diseases affecting the tubers or controllable by seed selection are treated in Farmers' Bulletin 544, Potato-tuber Diseases, and in Department Bulletin 64, Potato Wilt, Leaf-roll, and Related Diseases.

nearly full grown, very little of the potato plants except denuded or bare stems and dry and black foliage remains. Afterwards the beetles and larvæ attack eggplant and other plants of the potato family.

The distribution of the potato beetle (see fig. 1) covers practically the entire United States from the Great Plains eastward to the Atlantic coast, excepting the extreme southern parts of Florida, Alabama, Mississippi, and Louisiana. In Texas it occurs in the tropical region bordering the Gulf of Mexico. It also occurs in restricted parts of Washington, Oregon, Idaho, Arizona, Montana, Wyoming, Colorado, and New Mexico. In a few of these States it is present, but not as a pest—for example, in some regions of Colorado, where it feeds on a wild plant belonging to the potato family. It is constantly extending its territory as a pest.

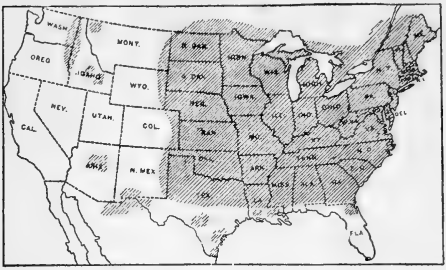

FIG. 1.—Map showing, by shaded areas, approximate distribution of the Colorado potato beetle.

The potato beetle is well known to all growers of potatoes. The beetle is robust and yellow, and its wing-covers are ornamented with 10 black lines (see fig. 2, *a;* fig. 3, *a*). It is three-eighths of an inch long. The "slugs" (young, or larvæ) (fig. 2, *b;* fig. 3, *c, c, d, d*) are dark red when first hatched, becoming paler with larger growth. They are slimy, soft in texture, and of disgusting appearance. The pupa, or resting stage, is shown at *c* in figure 3. The eggs (fig. 3, *b, b*) are orange colored and are deposited in masses.

The Colorado potato beetle feeds on practically all plants of the potato family, attacking potato, eggplant, tomato, ground cherry, and Jimson weed, besides other weeds of this family.

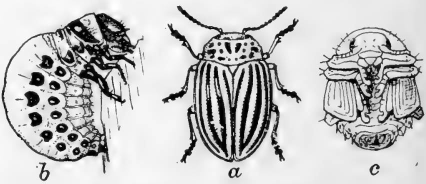

FIG. 2.—Colorado potato beetle: *a*, Beetle; *b*, larva, or "slug"; *c*, pupa. Enlarged.

In the more northern range of this insect there is probably only one generation a year, or, exceptionally, two generations. Farther southward three more or less complete generations occur. This insect pest passes the winter in the beetle stage from a few inches to several feet underground.

FIG. 3.—Section of potato plant showing Colorado potato beetle at work: *a*, Beetle; *b*, *b*, egg masses; *c*, *c*, half-grown larvæ; *d*, *d*, mature larvæ. Somewhat enlarged.

The beetles appear early in the spring, and with the first warm days may be seen in flight. As soon as the female can reach suitable plants after feeding she begins to lay her eggs. A single female is capable of producing between 1,800 and 1,900 eggs. Normally all the eggs hatch, and the entire life cycle from egg to egg may be passed in midsummer in a high temperature in five or six weeks. The possible progeny, therefore, is enormous.

Were it not for the fact that numerous species of insects and animals destroy large numbers of the beetles and "slugs" annually, the pest would be much more abundant than it is. (See fig. 4.) Setting aside the insects, of which between 30 and 40 species have been observed actually to prey upon this pest, the bobwhite or quail, robin, crow, and several other birds either pick the beetles from the vines or dig them from the earth, and skunks, snakes, and toads frequently gorge on them. Domestic fowls, especially ducks and guinea fowl, also are of assistance in suppressing this pest.

HOW TO CONTROL THE COLORADO POTATO BEETLE.

The Colorado potato beetle is not difficult to control, no other method being necessary than the free use of arsenical preparations (see figs. 5 and 6) and mechanical devices. The following procedure is advised when this insect alone is to be combated. In the majority of cases, particularly in the Northern States, the combined treatment outlined on page 18 should be followed.

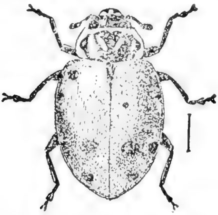

FIG. 4.—A ladybird (*Hippodamia convergens*) which preys on the eggs of the Colorado potato beetle. Much enlarged.

SPRAYING WITH ARSENATE OF LEAD.

As a spray for the potato beetle and similar pests, arsenate of lead, or lead arsenate, serves the same purpose as Paris green and its use for the last two years or more shows that it is even more valuable than Paris green. Conditions incident to the great war have caused a scarcity of copper compounds and the price of Paris green is so high that it can not be used economically.

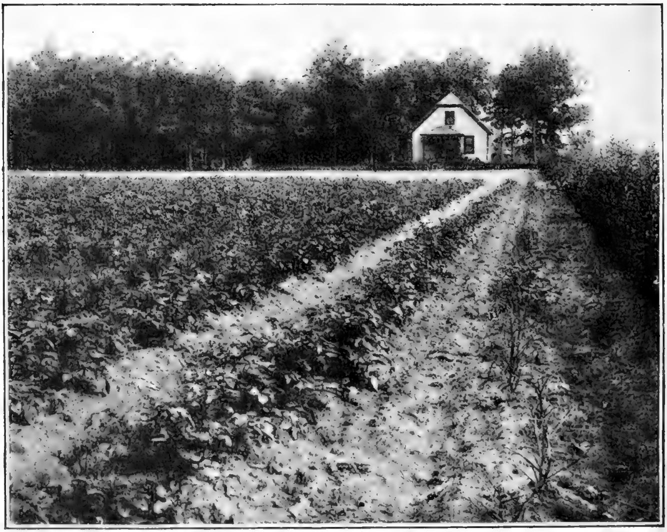

FIG. 5.—Field of potatoes showing outside row unsprayed in comparison to the remainder of the plat sprayed for the Colorado potato beetle with Paris green, one-half pound to 50 gallons of water.

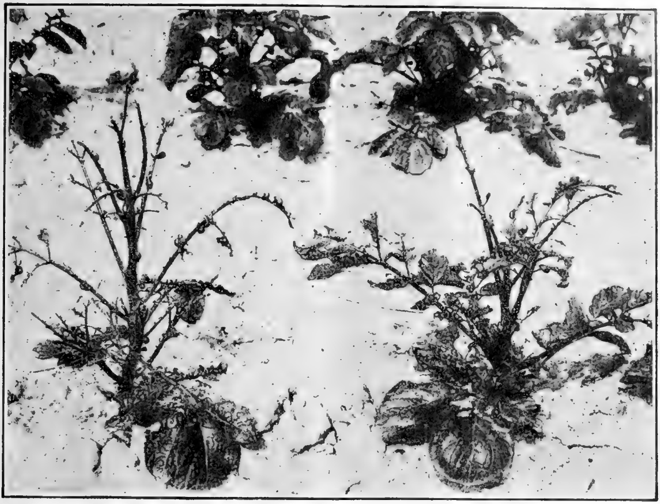

FIG. 6.—In foreground, potato plants not sprayed for the Colorado potato beetle; in background, sprayed potato plants.

Arsenate of lead has the following advantages over Paris green: (1) It contains less soluble arsenic; (2) it is less harmful to young growing plants, and when applied in the proper manner and at the proper strength does not scorch them; (3) it adheres more strongly to the foliage; (4) it is less troublesome to prepare; and (5) it is of greater value than other arsenicals (except zinc arsenite) in that it leaves a white coating on the foliage, so that its presence or absence can be determined readily after spraying.

The adhesiveness of spraying material is promoted by the addition of the same weight of soap as of the arsenical used. The soap may be either resin fish-oil, or laundry soap, preferably the former.

The formula is as follows:

Arsenate of lead (powder)	pound..	1
Soap for "sticker"	do....	1
Water or Bordeaux mixture	gallons..	25

If the paste form of arsenate of lead is used, 2 pounds to 25 gallons of the liquid is the proper proportion.

For small gardens two-thirds of an ounce, or 10 level teaspoonfuls, of the powder to 1 gallon of water is used.

Two or three sprayings ordinarily will suffice for the spring generation if applied before the eggs are hatched, and about the same number should be employed for the second generation. One or two sprayings for the third generation, when it appears, also should be given.

Precaution to prevent poisoning.—Arsenate of lead and other insecticides should be labeled properly and the word POISON should appear on the package. It is best to keep poisonous substances under lock and key and where children can not reach them.

Utensils employed in the preparation of arsenate of lead should be cleaned thoroughly after use.

OTHER REMEDIES.

Jarring, if done early in the season, is of value for small crops. It is performed usually by brushing the beetles and "slugs" into large, shallow milk pans or similar receptacles containing a little water on which a thin scum of kerosene is floating. Egg masses should be clipped off whenever observed and destroyed promptly.

FIG. 7.—Black blister beetle: Adult. Enlarged.

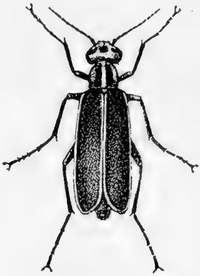

FIG. 8.—Margined blister beetle: Adult. Enlarged.

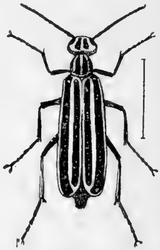

FIG. 9.—Striped blister beetle: Adult. Enlarged.

Fall and spring plowing, while valuable for most insects which pass the winter in the ground, are less valuable for the potato beetle, because hibernation takes place far under the surface and very deep plowing would be necessary.

Hand picking is effective early in the season, but later is too slow and laborious.

BLISTER BEETLES.

Potatoes are subject to injurious attack by blister beetles of several forms. These beetles are slender, comparatively soft bodied, and variously colored. All are general feeders, and a large proportion of them prefer potatoes to other foods. One of the commonest of these is the black blister beetle (fig. 7) [1]. It appears at about the time of the flowering of wild aster and goldenrod, and is known also as the "aster bug," Besides potato, it attacks beans, peas, cabbages, and various other plants. Other common species are the margined [2] and

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[1] *Epicauta pennsylvanica* DeG.

[2] *Epicauta marginata* Fab.

the striped[1] blister beetles, shown in figures 8 and 9. These insects are gregarious and migratory in habit, feeding most voraciously, running rapidly, and flying from time to time. Frequently they descend on a crop and ruin it in a few days, eating both foliage and stems. They appear at different times, according to temperature, usually being most abundant from July to September.

REMEDIES FOR BLISTER BEETLES.

Arsenate of lead is the best remedy for blister beetles. It is prepared and applied as directed for the Colorado potato beetle. In addition, in some portions of the West a line of boys and men is sent through infested fields to drive the beetles ahead of them by short flights or running until they alight or come to rest in windrows of hay, straw, or other dry material, which previously has been prepared along the leeward side of the field. When the beetles take refuge in such a windrow it is burned promptly. This procedure has been followed with success.

Prompt application of remedies at the very outset of attack is necessary to save the crop.

FLEA-BEETLES.

Potatoes are attacked every year by flea-beetles, some of which are specific enemies of the crops of the potato family. Flea-beetles begin their work early in the season. The beetles riddle the leaves of young and tender plants with punctures, causing the leaves to die, thus depleting the vitality of the plant; and the larvæ, or young, feed at and injure the roots. These insects, a little larger than a flea, derive their common name from their small size, and from the fact that their powerful hind legs enable them to take long leaps.

The most important of these insects is the potato flea-beetle.[2] (Fig. 10.) This species occurs practically throughout the potato-growing regions of the country from Canada and New England to the Gulf region and in some districts in California. The most severe injury, however, is done in the North. The larva is the cause of "pimply" potatoes, which bring a lower price in the market, sometimes 5 cents a bushel less than the regular price. Eggplant, tomato, and tobacco also are attacked, and when this insect is numerous it sometimes attacks other plants. Occasional injury is done to potatoes and tomatoes through gnawing of the sprouts. Eggs are laid early in May or June, and the life cycle may be completed in midsummer in about 35 days.

During recent years this species has shown a great fondness for tomato, and during the spring and summer of 1917, from April 19 to about the middle of July, injury was widespread. In the case of tomato, the plants were sometimes destroyed by defoliation when

[1] *Epicauta vittata* Fab. [2] *Epitrix cucumeris* Harr.

potatoes also were present. The aggregate of attack shows injury about equal on these two crops. Attack was so sudden and severe that no remedies were applied so far as could be learned.

The eggplant flea-beetle[1] (fig. 11) and the tobacco flea-beetle[2] (fig. 12) also attack potato, but each is more common on the plant from which its English name is derived.

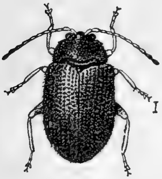

FIG. 10.—Potato flea-beetle: Adult. This species does much injury to young plants. Actual length shown by line at right.

REMEDIES FOR FLEA-BEETLES ON POTATO.

When potatoes are sprayed with arsenate of lead for the Colorado potato beetle and with Bordeaux mixture for diseases, these beetles are repelled to a considerable extent. Because of their active jumping and flying habits these insects are not likely to remain on the plants during spraying, and so are not poisoned, but they do not seem to attack foliage that has been covered properly with either spray material.

Although the subject of experiment for many years, the most efficient remedy for the potato flea-beetle remains to be found. The general opinion seems to be, however, that Bordeaux mixture alone, acting as a repellant, is the best.

All wild plants of the potato family should be pulled up or otherwise destroyed throughout the season in order that the insects may have no other breeding place.

CUTWORMS.

Cutworms frequently do considerable damage to potatoes early in the season and sometimes later. They feed chiefly at night and in the shade, cutting off the young plants about even with the ground. A common species is the so-called granulated cutworm,[3] shown in figure 13.

The best remedy for cutworms is poisoned bait. To mix and apply this bait take a bushel of dry bran, add 1 pound of white arsenic or Paris green, and mix it thoroughly into a mash with 8 gallons of water, into which has been stirred 2 quarts of sorghum or other cheap molasses. This amount will be sufficient for the treatment of about 4 or 5 acres of cultivated crops. After the mash has stood for several hours, scatter it, in lumps about the size of a marble, over the fields where the injury is beginning to appear and about the bases of the plants attacked. Apply the bait late in the day, so as to

FIG. 11.—Eggplant flea beetle, an insect which also attacks potato: Adult. Greatly enlarged.

[1] *Epitrix fuscula* Cr. [2] *Epitrix parvula* Fab. [3] *Feltia annexa* Treit.

place the poison about the plants before night, which is the time when the cutworms are active. Apply a second time if necessary. If this mash is made up with less water it may be applied with a grain or fertilizer drill to good advantage.[1]

Caution (see p. 8).—Arsenic and Paris green are deadly poisons. Handle them with great care. Keep children, live stock, and poultry away from this bait.

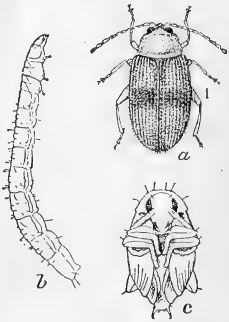

FIG. 12.—Tobacco flea beetle, an insect which also attacks potato: *a*, Adult, or beetle; *b*, larva, side view; *c*, pupa from below.

LEAFHOPPERS AND PLANT-LICE.

Leafhoppers sometimes are very injurious to potatoes. The bean leafhopper,[2] a small green insect (fig. 14), has been described as "probably our worst all-around leafhopper pest, so exceedingly abundant that notwithstanding its varied diet it is able to make serious attack on quite a number of cultivated plants on its list." Among its chief food plants are potatoes, sugar beets, beans, cowpeas, celery, currants, and apple and other trees. From its abundance on the apple it is known as the apple leafhopper. During the year 1914 the Bureau of Entomology received information from Pennsylvania and New York that this species was the cause of a "blight." Samples of the injured leaves had the appearance of having been burned and scalded, but the dead leaves showed no evidence of early-blight, and the evidence was strong that injury was due to the bean leafhopper or the potato aphis,[3] or both, in the States mentioned, as no other insects were observed at that time, not even the Colorado potato beetle. Fortunately, both insects were destroyed by storms on Long Island and in New Jersey, New England, Pennsylvania, and the upper Hudson River region of New York.

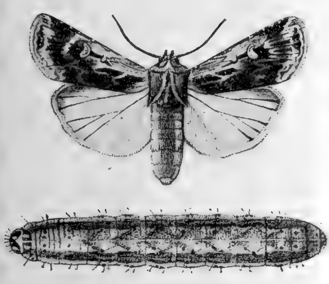

FIG. 13.—Granulated cutworm, an injurious potato insect: Moth above; cutworm, or larva, below. Somewhat enlarged.

During the year 1917 the spinach aphis[4] became extremely abundant, its ravages extending from the Gulf region northward to New England and westward to Illinois and Minnesota. The principal

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[1] Additional information with regard to cutworms may be obtained upon application to the Bureau of Entomology, U. S. Department of Agriculture.

[2] *Empoasca mali* LeB.

[3] *Macrosiphum solanifolii* Ashm.

[4] *Myzus persicæ* Sulz.

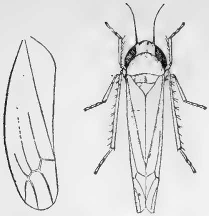

FIG. 14.—Bean leafhopper, an insect which is also injurious to potato: At right, adult insect; at left, wing extended, showing venation. Much enlarged.

injury was to potatoes, followed by tomatoes, cabbages, and many other food plants. In most cases it caused the greatest consternation and fear of losses, especially among owners of small gardens, who were absolutely unacquainted with the insect and the remedies to apply for it.

Leafhoppers and plant-lice do not feed upon leaf tissue, but insert their beaks into the tissue and drain the vital juices of the plants, thus weakening them so that a great reduction in the yield of potatoes results.

SPRAYS FOR LEAFHOPPERS AND PLANT-LICE ON POTATO.

Nicotine sulphate, a contact insecticide, has been used experimentally as a spray against the bean leafhopper and the potato aphis on potato, and its use has been attended with some success. The standard formula is as follows:

Nicotine sulphate, 40 per cent solution	pint..	$\frac{3}{8}$
Fish-oil or other soap, dissolved	pounds..	2
Water	gallons..	50

Everything considered, nicotine sulphate is for several reasons preferable to kerosene emulsion or soap solutions, is more easily prepared, and is manufactured as a standard solution, containing 40 per cent, by weight, of nicotine. Usually it is used at a dilution of 1 part of 40 per cent solution to 1,000 parts of water. For a "spreader," or "sticker," about an equal quantity (see formula), or a little more, of soap is added to the entire solution. Common yellow bar soap is perfectly satisfactory for ordinary purposes. For thoroughness this solution should be applied in as fine a spray as possible. Most insects are reached more readily by a fine mist, but for sucking insects the spray should be applied at considerable pressure so that every insect is actually reached or hit by it.

For use in small gardens, 1 teaspoonful of nicotine sulphate is used in 1 gallon of water, and to this a 1-inch cube of hard soap is added and the whole thoroughly mixed. If a larger quantity is needed, 1 fluid ounce of nicotine sulphate, 8 gallons of water, and one-half pound of soap are used. Directions are furnished on the covers of packages, and frequently instructions accompany them.

Kerosene emulsion, applied as for other sucking insects, is valuable also but is being superseded by nicotine sulphate solutions.[1]

For leafhoppers alone, as they occur on potato, bean, and other plants, still another remedy is used, a capturing device called a

[1] Directions for the application of kerosene emulsion will be furnished by the Bureau of Entomology, U. S. Department of Agriculture.

"hopperette," or hopperdozer. One of these is shown in figure 15. An account of others to be used on a larger scale is furnished in Farmers' Bulletin 747, Grasshopper Control.

During the present growing season (1917) to date it has been astonishing to learn how many growers have used Paris green and arsenate of lead as remedies for plant-lice. They are not only absolutely worthless against plant-lice, but sometimes they destroy some other insects which prey upon and which might otherwise greatly reduce the numbers of the plant-lice. Arsenate of lead and Paris green are stomach poisons and effective only against pests which devour leaf tissue.

LATE-BLIGHT AND ROT.

Late-blight is the most destructive potato disease. Originating in South America, it has spread to every potato country in the world and has destroyed crops to the extent of causing famine, as in Ireland in 1845.

In the United States late-blight is most common in the Northeastern States, as indicated on the map, figure 16. In the shaded areas in bad years 50 per cent of the crop in unsprayed fields may be destroyed. It occurs every year in northern New England, and usually visits New York and parts of the adjacent States; in wet seasons it extends as far west as Iowa and Minnesota. It occurs to some extent in the south Atlantic trucking sections from April to June and in the southern mountain region in autumn. The moist, cool climate of portions of the Pacific coast favors its development; but it is seldom or never found in the Great Plains, the Rocky Mountains, and other dry or hot parts of the country.

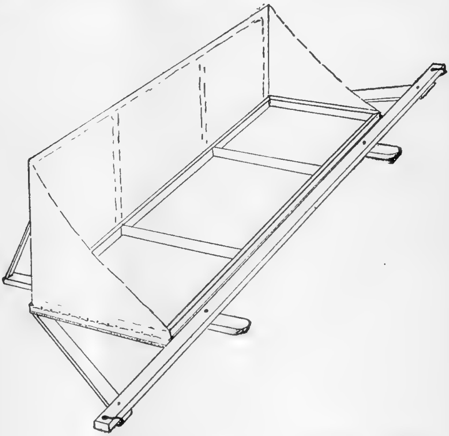

FIG. 15.—A successful type of horse-drawn hopperdozer. (Milliken.)

APPEARANCE OF LATE-BLIGHT AND ROT.

Late-blight develops after the blossom period and does its greatest damage toward the end of the growing season. It appears as purplish black or brownish black spots on the leaves, which, if examined when moist with dew or rain, show a delicate, powdery bloom on the underside. (See fig. 17.) The stems are attacked later, and the entire plant may be destroyed in a few days. If weather conditions favor the disease, fields go down within a few days as if swept by fire, and a foul odor characteristic of the disease is very perceptible.

The blighting of the foliage is followed by decay of the tubers, owing to spores washed down through the soil from the foliage. If the soil is wet and heavy, there may be a rapid soft-rot caused principally by bacteria. The typical late-blight tuber injury, however, is a dry rot which develops in the field or after storage, as sunken brown spots near the outside of the tuber.

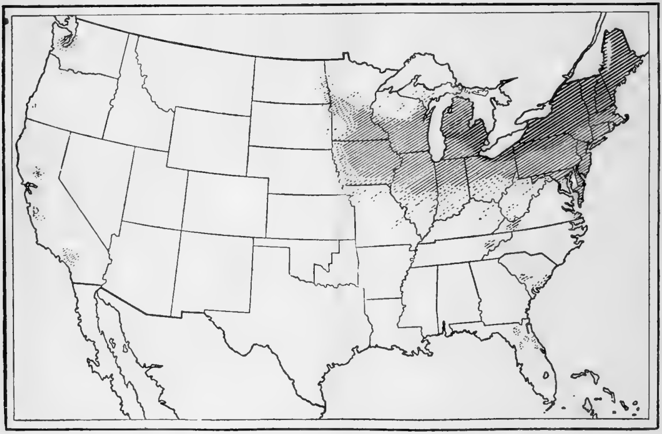

FIG. 16.—Map of the United States showing the distribution of potato late-blight. The sections where the disease is the more prevalent are indicated by the heavier shading.

CAUSE OF LATE-BLIGHT.

Late-blight is due to a fungus[1] which lives as a parasite on the potato plant and some of its relatives, notably the tomato. This fungus is itself a plant formed of slender, moldlike filaments (mycelium) which penetrate the potato plant and feed upon it and later produce vast numbers of minute spores or fruiting bodies. These are spread by wind and water to other plants, which may become infected and produce another crop of spores within five or six days. The tubers become infected by spores washed down through the soil or by contact with blighted tops when digging is being done.

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[1] *Phytophthora infestans* (Mont.) DeBary.

FACTORS INFLUENCING LATE-BLIGHT.

The origin of the infection.—Late-blight does not occur in the soil. It overwinters in stored tubers. Potatoes with more or less dry rot 18) are planted frequently, and some of them give rise to weak sprouts. The fungus grows up these shoots and produces spores on the above-ground parts, which are carried to adjacent plants and start centers of infection. Such first cases of late-blight often are present in the fields two weeks or more before the disease becomes epidemic.

In preparing potatoes for planting it is important to reject seed potatoes affected with late-blight dry rot, as infected tubers often decay in the ground without germinating, but there is little hope of avoiding the disease by this precaution, since under favorable weather conditions blight is carried many miles in a short time. No method of treating seed potatoes to kill late blight has been found practicable. Thorough spraying with Bordeaux mixture is the only preventive.

FIG. 17.—Potato late-blight.

Temperature.—Late-blight spreads most rapidly when the daily mean temperature is 72° to 74° F. with abundant moisture. Weather which in the North is designated as "warm and muggy" is therefore favorable to the rapid development of late-blight, whereas the hot summer weather of the Southern and Central States checks it completely.

Moisture.—In dry weather the production of spores is checked, and the disease ceases to spread because the spores can not germinate except in the presence of moisture. Dry foliage can not be infected. It is only when drops of

FIG. 18.—Late-blight tuber-rot.

water from rain or heavy dews stand for some hours on the leaves that the disease can gain a foothold. This is an important point to remember in connection with spraying; it explains why all portions of the plant should be covered with Bordeaux and why protection with the spray before rain is needed.

FIG. 19.—Potato tipburn.

Soil and location.—Hollows or low places in the fields, wherever moisture remains longest, are most likely to develop late-blight, and potatoes on clay soils are likely to suffer more from rot than those on sandy soil.

Varieties.—Partially resistant varieties of potatoes have been bred in Europe, but these are not well adapted to American conditions. We are now developing our own resistant strains, but at present no variety which meets the requirements for a standard commercial sort can be recommended as disease resistant. Select the best variety for your locality and market, and protect from late-blight by spraying with Bordeaux mixture.

PREVENTION OF LATE-BLIGHT TUBER-ROT.

1. *Spraying.*—The first essential is to spray, as recommended on page 18.

2. *Date of digging.*—It is unwise to dig potatoes when the first blight appears. The immature tubers are not in condition to keep well and they become infected by contact with the tops while being harvested. Consequently, the potatoes should not be dug until a week or more after the tops are entirely dead.

3. *Sorting and storage.*—Immediately after harvesting, sort out all potatoes showing any trace of dry rot and store the remainder in a dry cellar or storage house, kept cool, as near 36° F. as possible. Dry rot will not develop at this temperature, but in a warm place it will be spread from tuber to tuber.

No treatment with lime, formaldehyde, or other disinfectant is of any value against late-blight dry rot.

OTHER DISEASES.

Several other diseases of potato foliage should be mentioned, to avoid confusion with late-blight. They are listed below in the order of their appearance.

SUNSCALD.

Young potato plants that have made a rapid growth during cool and moist weather may suffer from hot, bright weather. The leaves droop and wilt, and some are killed, but the plants usually recover.

TIPBURN.

Protracted hot and dry weather, complicated by flea-beetle injury and early blight, results in the injury illustrated in figure 19. The tips and margin of the leaves turn brown and dry up. The yield of tubers is reduced in proportion to the loss of foliage. Spraying with Bordeaux mixture greatly reduces the injury from tipburn.

EARLY-BLIGHT.

Early-blight is a fungous disease which appears in the North before the late-blight. In the South, however, it is more common on the fall crop. It is likely to occur in all sections of the country.

This disease is marked by the appearance of nearly black spots in the otherwise green leaves. As these enlarge they are marked by faint concentric rings. (See fig. 20.) Eventually the leaves yellow and die, and the tuber yield is reduced 10 to 25 per cent.

FIG. 20.—Potato early-blight.

Early-blight attacks weakened plants and is worst upon light soils, not well adapted, by fertility and moisture supply, to potato growing. When conditions favor, it becomes widespread.

The combined treatment advised below includes Bordeaux mixture for early-blight.

ARSENICAL POISONING.

The use of Paris green in water in large quantities results in a burning of the leaves, often in concentric spots centering at flea-beetle punctures, somewhat resembling early-blight. When the arsenical is combined with Bordeaux mixture, this injury is avoided.

COMBINED TREATMENT FOR DISEASES AND INSECTS.

Watch the young plants closely and spray with Bordeaux mixture and arsenate of lead as soon as the first evidence of the Colorado potato beetle or of flea-beetles is noted.

Repeat this application every 10 to 14 days to keep all of the new foliage protected. If no insects are present and the weather is dry, the intervals between sprayings may be lengthened.

As the late-blight season approaches, which in the North usually is after the middle of July, a protective spraying should be given and the weather watched more closely, for if continuous showers occur, with a mean temperature of 72° to 74° F., spraying every 5 to 7 days will be necessary.

A system for reporting the appearance and progress of late-blight should be organized in order that potato growers may be warned when to increase their efforts.

VALUE OF SPRAYING.

Throughout the late-blight area shaded on the map (fig. 16) it pays to spray potatoes with Bordeaux and arsenicals, whether blight develops or not. With few exceptions, large gains in yield are due to protection from flea-beetles, grasshoppers, early blight, tipburn, etc.

This fact has been established by extensive experiments which have been conducted in New York and Vermont. During a 10-year period, at different experiment stations in New York State, an average gain of 60 bushels per acre was secured. At the Vermont station, during a 20-year period, which involved all possible seasonal variations, an average gain of 105 bushels per acre, or 64 per cent over the unsprayed, resulted.

In addition, records taken from a business point of view on a series of experiments of a nine-year duration, conducted by farmers under the direction of the New York State Experiment Station, show large gains. The average cost of spraying, including materials, labor, and wear and tear on machinery, was $4.74 per acre. The nine-year average increase in yield due to spraying was 361 bushels per acre, making a net profit of $14.43 per acre. When these experiments were conducted the cost of materials was less than at the time this bulletin was written, but the increased product warrants an increased expenditure.

The value of such applications of spray annually in regions not included in the blight area (fig. 16) is not so well established. Conditions in the Atlantic coastal region from New Jersey to Florida, for instance, are so different from those farther north that spraying can not be expected to give as large returns as in Maine or New York. In Florida there have been several years when late-blight has prevailed and spraying has been profitable. Here the argument for crop insurance is stronger and spray applications may be advised in number proportioned to the frequency of rain, but always thorough. In New Jersey also, as conditions begin to approach those of the North, gains from spraying may be expected. This is equally true in other regions of the United States, where blight occurs only in occasional years.

The foregoing figures show, however, that spraying is very profitable in districts where potato insects and diseases annually take a big toll. The most successful growers in these districts, who wish to be insured against loss, practice thorough and consistent spraying, knowing that there will be large returns on their investment.

SPRAYING APPLIANCES.

For home gardens small hand sprayers of varying cost and efficiency are to be had. Consult Farmers' Bulletin 856.

For the farm potato patch, where from one-half acre to 3 acres are grown and where orchard trees or small fruits are to be sprayed, a barrel spray pump of good capacity is recommended. This hand pump is mounted on a 50-gallon barrel and carried on a homemade two-wheel cart or in a farm wagon.

If a cart is used the nozzle may be fastened to the back to spray four rows, but to do good work with this it is necessary, as with the lighter traction sprayers, to go over the field twice, the second time in the opposite direction.

More thorough work can be done by hand spraying if the pump is fitted with one or two lines of ½-inch hose, 25 feet long, ending in a 4-foot gas-pipe extension. This requires a man for each line and one to pump.

All commercial growers should provide themselves with the most effective traction sprayer they can secure. In these the pump is operated by a chain or gear drive from the wheels. It pays to get the best, as a high pressure of 120 to 150 pounds is needed for effective work. (See fig. 21.)

A good nozzle is one of the most important parts of a spray outfit. The cyclone or eddy chamber type, of which the Vermorel is an

FIG. 21.—Horse-driven air-power sprayer in use in a potato field.

example, are the best. The spray produced should be in the form of a fine mist covering every part of the plant.

For truck gardens the common compressed-air sprayer employing a tank holding 3 or 4 gallons and provided with a pump for developing the air pressure is the most effective type. An automatic cut-off in the spray rod retains the liquid in the tank until the desired pressure, as high as can be conveniently pumped, has been obtained. Then the liquid may be released as required. Such a machine costs \$5 to \$6 in galvanized iron, or \$8 to \$10 in brass. The latter is preferable, as it lasts longer and is less liable to corrosion by the chemicals used in spraying. (See fig. 22.) A smaller type known as the syringe atomizer, holding about a quart of spray mixture, and costing from 50 cents to \$2, according to construction, may be obtained from most seedsmen, and is suitable for small kitchen gardens.

HOW TO PREPARE BORDEAUX MIXTURE.

Bordeaux mixture is the only fungicide that has any practical value against potato diseases. Lime-sulphur, powdered sulphur, and other new mixtures that have come into use in orchards are injurious to the foliage, or weaker in fungicidal action, or both. The experiments to date show that for potatoes and other truck crops nothing has yet been found to replace the copper fungicides. The ingredients and method of preparation are as follows:

Copper sulphate	pounds..	4
Quicklime	do....	4
Water to make	gallons..	50

Prepare the copper sulphate by suspending it in a gunny sack just below the surface of several gallons of water in a clean barrel. When the sulphate is dissolved, which requires three or four hours, remove the sack and stir into the barrel enough additional water to make exactly 25 gallons of the copper solution.

Prepare the lime by slaking it slowly and thoroughly in a clean barrel, strain, and add enough additional water to make exactly 25 gallons of lime milk. Stir thoroughly.

Pour the two ingredients together into another barrel or, better, directly into the spray tank, if it will hold 50 gallons. It is highly important to stir the mixture very thoroughly and to strain both ingredients before they are combined, as otherwise clogging of the spray nozzles might result. Use copper or bronze wire strainer of 18 meshes to the inch. Do not put copper sulphate or Bordeaux mixture into tin or iron vessels; use wood or copper containers. Mix the Bordeaux as needed and apply at once. It is never so good after it has settled.

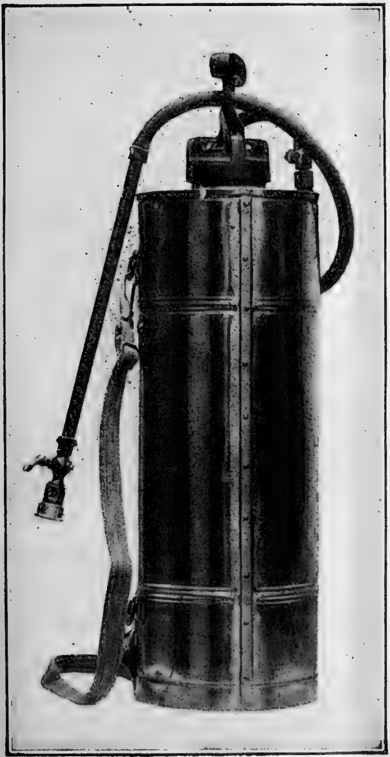

FIG. 22.—Compressed-air sprayer standing upright, showing hose, nozzle, and other attachments.

STOCK SOLUTIONS.

Everyone who uses Bordeaux mixture frequently and in quantity will find it convenient to keep on hand concentrated stock solutions of copper sulphate and of lime in separate containers. These stock solutions keep indefinitely if the water which evaporates is replaced.

Build an elevated platform to hold the barrels. Some time before the day on which you wish to commence spraying, suspend 50 pounds of copper sulphate to dissolve in a 50-gallon barrel of water. Slake 50 pounds of lime in another barrel. Add water to make 50 gallons of lime milk. When Bordeaux mixture is needed, stir both stock barrels and take from each as many gallons as the formula calls for in pounds. Dilute the copper sulphate in one barrel and the lime milk in another, each with half the water, and let the two run together into the strainer of the spray tank. Add the arsenate of lead or other poison, and stir well. Thorough agitation is important in making a good Bordeaux mixture.

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THE BOLLWORM OR CORN EARWORM

F. C. BISHOPP

Entomologist, Insects Affecting the Health of Animals

FARMERS' BULLETIN 872

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C. October, 1917

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THE BOLLWORM or corn earworm is an important pest of cotton, corn, tomatoes, and tobacco. It feeds also on many other cultivated and wild plants.

As the winter is passed in the pupa or resting stage, 4 to 6 inches below the surface of the soil, late fall or winter plowing will cause the death of many pupæ. This is probably the most important of all control practices.

Since the insect increases greatly in numbers late in the season and hard bolls of cotton and ripening corn ears are largely immune to attack, it is important that these crops be matured as early as possible.

The caterpillar, except when it first hatches from the egg, feeds by boring into the fruit or stalk of the plants attacked; hence poisoning must be done at the right time to give best results. Poisoning of cotton with powdered arsenate of lead or Paris green should take place when the corn ears in the main crop become hard; that is, about July 10 to August 20, according to latitude and season. Tomatoes may be largely protected by applications of the poison, begun as soon as injury to the plants appears and repeated at weekly intervals until 10 days before picking. Tobacco buds may be treated by dropping a teaspoonful of a mixture of arsenate of lead and corn meal into them.

Corn used as a trap crop gives some protection to cotton and tomatoes. For cotton the corn should be planted so as to come into silk and tassel when the ears of the early crop are hardening. To protect tomatoes the corn should be planted at intervals so as to be kept in silk through the greater portion of the fruiting period of the tomatoes.

THE BOLLWORM OR CORN EARWORM.[1]

CONTENTS.

COTTON BOLLWORM, corn earworm, tomato fruitworm, and false budworm of tobacco are common names applied to one and the same insect when it is found attacking these various crops. In fact the insect is a very general feeder, attacking many wild plants as well as garden vegetables, alfalfa, cowpeas, and the crops indicated above.

The bollworm, or corn earworm as it is most widely known, occurs as a pest in practically all parts of the United States. The corn crop is widely affected, and the loss to this crop, including sweet corn, exceeds the damage to any other single crop. This was estimated in 1905 to be about $18,000,000 annually, and in the absence of the later statistics it is safe to assume that the annual losses at the present time greatly exceed this amount. The loss to cotton raisers on account of its depredations was placed at $8,500,000 each year. This injury to cotton is most severe in parts of Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Alabama. (See fig. 1.) The total annual tax of this insect on the farmer can be conservatively placed at nearly $30,000,000. Despite these startling figures, the fact that the insect has been present as a pest in this country for many years has caused most farmers to become tolerant of it. Under the present stress

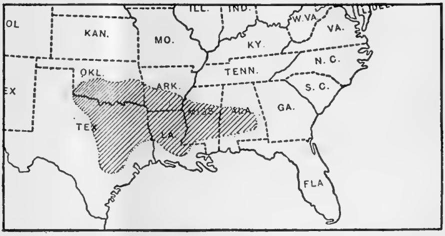

FIG. 1.—Map showing approximately the area in which the bollworm inflicts severe injury on cotton.

[1] Known scientifically as *Chloridea obsoleta* Fab.; order Lepidoptera, family Noctuidae.

of world need it becomes doubly necessary to put forth every effort to reduce these losses to a minimum.

CHARACTER OF INJURY.

The character of attack on all the principal crops affected is similar. The caterpillars usually bore into and feed within the

FIG. 2.—Young corn plant showing injury to growing tip by bollworm. (Quaintance.)

plant tissue. The first damage to corn is caused by boring into the bud and eating down into the tender leaves as they unfold. (See fig. 2.) A little later this injury often seriously affects the tassels before they have opened out, and when the silks appear eggs are laid upon them and young corn earworms burrow down through the silks and attack the small kernels, as shown in the illustration on the title-page. The tips of the ears are injured first; later, especially in tender varieties such as sweet corn, the earworms sometimes eat completely to the base of the ear and almost destroy it. In some regions practically every ear of sweet corn is more or less damaged and throughout the entire country from 70 to 98 per cent of the ears of field corn are attacked. Following this injury molds frequently gain access to the ears and damage them still further. This is especially true during wet seasons. Such conditions are often followed by an abnormally large number of cases of death among stock from the so-called cornstalk disease which seems to be caused by certain molds which develop on corn.

FIG. 3.—Cotton boll with full-grown bollworm eating into tip. Natural size. (Quaintance.)

In the case of cotton the injury is readily distinguished from that caused by the boll weevil, as the squares and more tender bolls are completely eaten out, particularly after the worms have gained considerable size. Occasionally full-grown bolls are gnawed into by the large caterpillars and from one to all of the locks of cotton damaged. (See fig. 3.) Bolls which have become hard are seldom fed upon to any extent.

Injury to tomatoes consists principally of damage to the green or partially ripened fruit, but the young bollworms sometimes also bore into the growing tips of the plants and occasionally destroy the flowers as well.

In tobacco the injury consists of the penetration of the small leaves in the growing tip, hence the common name of budworm. A related caterpillar,[1] however, attacks tobacco in a very similar manner. A single caterpillar may render several leaves unfit for wrapper by penetrating the bud.

HABITS OF THE INSECT AND HOW IT DEVELOPS.

A general knowledge of the life history and habits of an insect is needed in order intelligently to combat it. The bollworm or corn earworm when mature (fig. 4) is a moth or miller about $1\frac{1}{3}$ inches across the spread wings. It varies in color from a light brown or olive green to pale yellow and it is commonly seen flying about in the evening. These moths feed upon nectar of various flowers and when mature they deposit from nearly 500 to almost 3,000 eggs. The eggs (fig. 5) are laid on various parts of the plant and to some extent upon weeds and upon the ground. They are white or yellowish in color, oval, and covered with minute ridges running from top to bottom and still smaller ridges across these. They are large enough to be seen readily with the naked eye. The eggs hatch in from $2\frac{1}{2}$ to 8 days or even longer, depending upon the temperature.

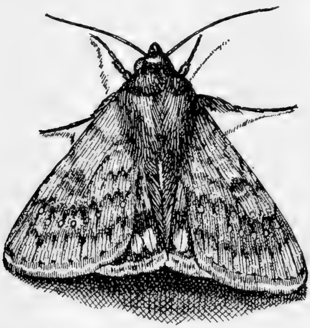

FIG. 4.—Bollworm moth with wings folded in natural position. About twice natural size. (Quaintance.)

When first hatched the larvæ or caterpillars are extremely small. They feed here and there on the surface of the plant near where the eggs were laid, but gradually work toward some tender portion within which they can bore. Growth is rather rapid, being completed in about 20 days. The larvæ shed their skins four or five times during this period. When full grown they are about $1\frac{1}{2}$ inches in length. The color varies from pale green to almost black. During the last few days of the life of the caterpillar it is capable of consuming large quantities of food, and it is during this period that it is most destructive.

FIG. 5.—Egg of bollworm moth, side and top views. Highly magnified. (Quaintance and Brues.)

[1] Known scientifically as *Chloridea virescens* Fab.

When fully fed the larvæ leave the plant and burrow into the ground, where they form a kind of cell in which they transform into chrysalides or pupæ of a mahogany brown color. (See fig. 6.) They remain in this quiescent stage for about two weeks except in the case of the last brood in the fall, which stays in the ground until warm weather the following spring. The depth at which these cells are formed by the larvæ in summer varies from 1 to 4 inches according

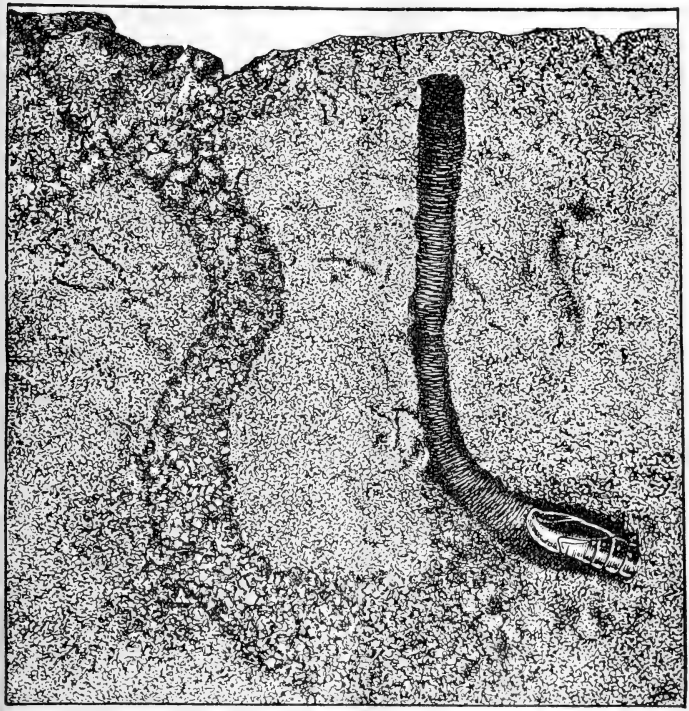

FIG. 6.—Vertical section through soil showing pupa of bollworm in its burrow. About natural size. (Redrawn from Quaintance and Brues.)

to the hardness of the soil. The overwintering pupæ are formed at somewhat greater depths, usually 4 to 6 inches. These chrysalides or pupæ produce moths which in turn lay eggs, thus completing the entire life cycle in about 30 days during warm weather.

That there is a definite connection between weather conditions and injury to the cotton crop by this insect is generally recognized. Cloudy and rainy weather during the latter part of July and throughout August undoubtedly is conducive to severe injury. This is partially explained by the moistening of the soil, which permits the moths to emerge without difficulty, and by the stimulating effect of the moisture on the growth of stalks and leaves of cotton at this time, which favors bollworm development. Furthermore, it has been found that the prevalence of such weather conditions lessens the effectiveness of certain minute parasites which prey upon the bollworm in the egg and larva stages.

SEASONAL HISTORY AND RELATION OF ABUNDANCE TO CROP GROWTH.

As has been stated, the bollworm or corn earworm pupa passes the winter months in the soil. Early in the spring the moths begin to come out, and by the time corn is "knee high" they are ready to deposit eggs. On account of the number of pupæ which die from adverse conditions in the winter, the first brood usually is small and the damage is not so appreciable. The second brood appears about the time the corn is in silk and tassel, and the number of moths is increased greatly. The caterpillars reach their full development about the time the ears of early corn become hard. In the South the third generation is the one which is destructive to cotton, the corn at this time being for the most part hard and dry. In the North this brood develops on late corn and other crops, and under usual weather conditions is the last brood of the season, while in the South four or even five broods may develop during a year. The late caterpillars feed on various green crops, including late cotton, cowpeas, and alfalfa. Thus in the Southern States most of the overwintering insects will be found in soil where cotton and other late-growing crops are raised, while in the North the late cornfields probably contain most of them.

The bollworm shows a preference for corn when this crop is "silking," and this fact can be utilized to some extent in protecting cotton and other crops from injury, as will be pointed out later. These caterpillars are cannibalistic, and when they come in contact with one another many of them are killed, which usually reduces the number of worms developing in a single ear to one, two, or at most three, whereas dozens of eggs may be laid upon a single strand of corn silk.

CONTROL MEASURES.

As a result of the study of the life history and the seasonal history of this insect it will be seen that there are four outstanding facts which can be made use of in control work:

First, the insects spend the winter in the pupa stage in the ground. They also spend some time between generations in the soil. This enables the farmer to destroy many of them by plowing at the proper time.

Second, the caterpillars feed for a time on the surface of the leaves before penetrating the tissues of the plant. This is the only time during which the insect can be poisoned successfully.

Third, the number of bollworms or earworms increases greatly as the season advances. This indicates a need for hastening the maturity of all crops affected.

Fourth, since green corn is preferred as food, it is possible to utilize this to some extent as a trap to protect cotton and other crops.

It has been found that by modifying slightly the usual farm practices much can be done toward lessening bollworm or corn earworm injury. Fortunately these modifications are such as to increase crop production, regardless of the presence of this insect. Another important point is that some of the recommendations for controlling this insect are equally applicable, irrespective of the crop grown.

FALL AND WINTER PLOWING.

Probably the most important single step in controlling the bollworm consists of thorough breaking of the land in which the worms have buried themselves for the winter, at some time during the late fall or winter months. Particular attention should be paid in this respect to the crops which are known to have bollworms developing during the late fall months. The practice of fall and winter plowing, aside from bollworm control, is desirable because it conserves moisture, puts the ground in better condition for planting, and enables the farmer to plant at the proper time the following spring.

It has been found that the breaking up of the cells in which the insect is spending the winter results in the destruction of practically every pupa through the action of cold and moisture. Since the cells of the wintering brood are formed at from 4 to 6 inches beneath the surface, it is important that the plowing be deep enough to reach them. It is desirable to plow or deeply disk the fence rows and other places where bollworms may have fed on various plants. This is also beneficial in destroying eggs of grasshoppers and hibernating places of chinch bugs and other destructive insects.

CONTROL ON CORN.

CULTURAL METHODS.

In addition to the employment of fall and winter plowing, the injury to corn can be reduced somewhat by planting as early in the spring as is compatible with getting the ground into good condition. The corn should be as nearly uniform in age as possible and every effort should be made to hasten growth and maturity. Keeping the crop free from weeds and grass during the growing season not only tends to increase the yield but also destroys hiding places of the moths.

POISONING CORN.

Unfortunately no very satisfactory method of poisoning the worms on corn has been devised. As many as 50 per cent may be destroyed, but the remainder will gain entrance to the ears and produce the usual injury. Recent work conducted in Kansas by Mr. J. W. McCulloch and in Missouri by Mr. Leonard Haseman indicates that the application of powdered arsenate of lead to the silks as soon as they begin to appear will reduce the injury considerably. Owing to the rapid growth of the silk and the fact that the eggs are deposited continuously, it is necessary to make a light application of poison at three or four day intervals to secure good results. In the experiments mentioned the poison was blown onto the ears with a dust gun or applied by hand with a cheesecloth bag. The cost of application and material probably would more than offset the advantage gained under field conditions, and this method will be more applicable in protecting sweet corn or corn grown especially for roasting ears, and in reducing the amount of injury to special selections grown for seed purposes.

CONTROL ON COTTON.

CULTURAL PRACTICES.

Several of the measures best calculated to reduce bollworm injury in the cotton-growing States are equally effective in checking the ravages of the boll weevil. No loss of money or energy results from putting such cultural practices into effect, even though the bollworm should not appear in very destructive numbers in any particular year.

To protect cotton from bollworm injury it is important (1) that early maturing seed be selected; (2) that the crop be planted as early as is consistent with getting a good stand and having the crop start off well; (3) that poor lands be fertilized, and cultivation be thorough and frequent. Every step should be taken which will hasten the early maturity of fruit and keep the plants in a healthy, growing condition. The reason for this can be seen readily when we know that the bollworms pass to the cotton when the corn becomes mature, and that hard bolls are not subject to injury. Since the moths hide in the foliage when the growth is luxuriant, those varieties which make comparatively small stalk without a superabundance of leaves are desirable. This also hastens the drying out of the bolls after they are grown. The early and complete destruction of cotton stalks as recommended for the boll weevil will prevent the maturity of many late bollworms and destroy a considerable number outright.

POISONING COTTON.

The use of poisons against the bollworm has met with considerable success when the poisons have been applied at the proper time. Attention has been directed to the fact that a large proportion (from 60 to 80 per cent) of the eggs deposited in cotton fields are placed elsewhere than on the squares and flowers. Following hatching, therefore, it is necessary for the young larvæ to travel a considerable distance before penetrating the fruit. During this rather aimless wandering the insect eats here and there from the surface of the leaves and stalks. During this short period in the existence of the larva it is susceptible to the action of various arsenical poisons.

The time for applying the poison varies slightly from year to year. The first application should be made when the corn ears are becoming hard. The actual date will range from about July 10 to August 20, according to latitude and seasonal conditions. Powdered arsenate of lead or Paris green should be used. The former is less poisonous to the insect but is not so apt to cause burning of the foliage. At this season the slight burning resulting from the use of Paris green is really immaterial. Arsenate of lead has the advantage of sticking firmly to the plants; even a light rain will not wash it off after it has once dried on. The poison can be applied in dust form or as a spray. The former usually is more practical, since water is not usually found in proximity to cotton fields, and more time is required in applying poisons in liquid form. If Paris green is sprayed on, it should be used at the rate of 1 pound to each 50 gallons of water, and 50 gallons will cover about 1 acre. The powdered arsenate of lead should be used at the rate of about 5 or 6 pounds per acre, and the Paris green, when used in dust form, at the rate of 2 to 3 pounds per acre, according to the size of the plants. When Paris green is used a field can be covered more economically by mixing the material with two or three parts of air-slaked lime, which also lessens the likelihood of burning. The poisons may be put on by the old-fashioned "bag and pole" method or, better, with a power blower or a hand blower mounted on a light wagon. The bag and pole method is fairly efficient and obviates the purchase of machinery.

These outfits are not difficult of construction. A 4-inch board about 18 inches longer than the distance between the rows is used for the pole. To form the bags at either end, four blocks of the same material, each about 4 inches long, are nailed endwise to the underside of the pole. One of these is placed at each end and the other two about 16 inches from these to form the ends for the rectangular-shaped bags. An inch or one and one-half inch hole is then bored through the pole about 8 inches from either end for pouring the poison into the bags. These holes are closed with corks when the outfit is in use. The sides of a rectangular piece of cloth are then tacked along each edge of the pole, and the ends to the sides and bottom of the blocks. If unadulterated Paris green is to be used, 8-ounce duck may be used for the bag, but lighter material is necessary for powdered arsenate of lead or Paris green mixed with lime. One of these outfits is shown in figure 7. The poison sifts out over the plants as the pole is jarred by striking it with a stick as it is carried across the back of a mule ridden between the cotton rows. Two rows are thus treated at once and from 15 to 20 acres can be covered by one man during the early morning and evening hours which are suitable for the work. It is best to apply the poison when the plants are moist with dew so that it will adhere to the foliage. It is also necessary to avoid windy periods.

Care should be taken to protect the animals used in this work from eating the poisoned plants and as far as possible from becoming too much covered with the poison.

Best results can be secured by making two or three applications of poison at intervals of about a week. In case of rain following the use of Paris green, the crop should be treated again immediately. In

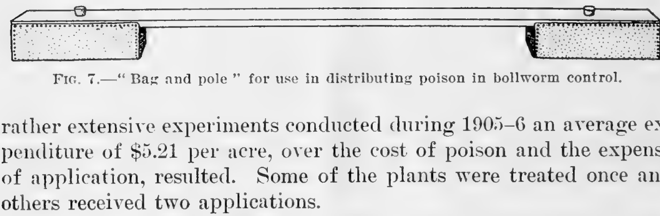

FIG. 7.—"Bag and pole" for use in distributing poison in bollworm control.

rather extensive experiments conducted during 1905–6 an average expenditure of $5.21 per acre, over the cost of poison and the expense of application, resulted. Some of the plants were treated once and others received two applications.

On account of the sporadic occurrence of bollworms in great numbers in most regions it is rather difficult to foresee just when serious injury is to occur, but it would no doubt be profitable to apply poison each year in the portions of Texas and Oklahoma where bollworm damage is general and most severe.

CORN AS A TRAP CROP TO PROTECT COTTON.

Since the bollworm prefers corn to cotton or most other plants for food it is possible to concentrate the larvæ on corn and keep them from becoming so numerous on cotton. To effect such a result it is important that corn be planted at such a time as to be in silk and tassel about the 1st of August. If it matures too early it will act only as a breeding place for bollworms, which will mature as the ears harden and a short time later transform to moths which in turn will deposit eggs over adjacent cotton fields. On the other hand, if the plants are in an attractive state, the moths, which fly quite freely, will assemble in the corn from considerable distances and deposit most of their eggs on the corn plants. These eggs will hatch and the young larvæ, being so numerous, will destroy one another to such an extent that usually not more than a few out of the many hatching on the silk of each ear will reach maturity.

One plan of planting the trap rows consists of leaving belts from 10 to 40 feet wide across the field at the time the cotton is planted and about June 1 planting this space with Mexican June corn in rows 5 or 6 feet apart. About 10 days later a row of cowpeas may be planted between the corn rows, thus leaving room for cultivation and at the same time furnishing attractive places for the bollworm moths, which will concentrate in the trap rows in great numbers. While any variety of corn may be used, the Mexican June corn is more desirable in the Southwest on account of its resistance to drought.

Another system is to plant patches of June corn and cowpeas here and there over the plantation following such crops as oats, wheat, and potatoes. This provides a trap crop for the bollworm, results often in a good yield of corn, and in a crop of cowpeas, which is valuable as green manure or for food and forage.

CONTROL ON TOMATOES.

The worms usually begin attacking the tomato crop before the fruit is set and continue their work until frost. At first they feed on the tender leaves at the tips and burrow into the stems. Later they attack the buds and flowers, then the small fruits, and continue the damage even when the fruit is ripening.

The feeding habits of the larvæ early in the season render the use of arsenical poisons effective, and as the worms pass from one fruit to another poison will destroy many of them later, but it is not advisable to use poisons later than 10 days before harvesting begins. As the first clusters of tomatoes are of greatest value, especially in the trucking regions of the South, the early use of poisons where bollworms cause trouble undoubtedly would net good returns.

On tomato lead arsenate should be used rather than Paris green in order to prevent burning. This material may be applied in dust form or as a spray. For the spray about 2 pounds of the lead arsenate in the paste form and 1 pound of zinc arsenate dissolved in 50 gallons of water should be used per acre. The use of about 3 pounds per acre of powdered arsenate of lead applied as a dust is recommended. The first application should be made as soon as the moths are observed in the field or injury to the leaves and stalks is noticed, and succeeding treatments should follow at about weekly intervals. If fungicides (such as Bordeaux mixture) are used against diseases of the tomato, the arsenical may be added to these.

While some are averse to using poisons on crops of this kind, no injurious effects are likely to occur, especially if the applications are discontinued some time before picking begins. The early treatments are most effective, as at this time the worms are not feeding within the large tomatoes and are thus most easily reached.

CORN AS A TRAP CROP TO PROTECT TOMATOES.

The principle of trapping described for the protection of cotton can be utilized in controlling the bollworm on tomatoes. It is advisable, however, to modify it somewhat. As the moths deposit eggs on the plants during a considerable period, it is desirable to have corn in silk and tassel from the time the fruit begins to set on the tomatoes until harvesting is over. It is advisable to use small areas immediately adjacent to tomato patches and plant portions of these at two-week intervals, thus bringing a succession of plants into silking during the fruiting period of the tomato. If a large acreage is in tomatoes, it is advisable to plant a few strips of corn through the field in addition to those on the margins. As the ears become sufficiently mature for roasting they should be gathered to prevent the escape of the worms. If these worms are allowed to leave the ears in the fields, they will produce moths which in turn may cause an infestation of the tomatoes. Either field corn or sweet corn may be used as a trap crop under these conditions.

CARE OF INFESTED FRUIT.

The poison treatment should be supplemented by picking and destroying all wormy tomatoes. These should not be left in the field, as the worms will emerge from them and return to the plants or produce moths which will multiply greatly the number of the worms later in the season.

CONTROL ON TOBACCO.

A number of authorities state that where the false budworm[1] is injurious to tobacco, notably in Georgia and Florida, damage can be prevented largely, though at a considerable expense, by sifting by hand into the bud a mixture of powdered arsenate of lead and corn meal. One pound of the poison is used to 75 pounds of corn meal[2] and applications to shade tobacco are made twice a week. No doubt corn can be utilized as a trap crop to some extent as recommended for the protection of tomatoes.

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[1] A local name for the bollworm, *Chloridea obsoleta* Fab.

[2] Extensive experiments have been made with many carriers, but none of them have given satisfactory results except the corn meal.

INEFFECTIVE METHODS OF CONTROL.

The burning of lights for the attraction of moths in fields is not uncommon in certain sections and the idea of trapping the moths by various devices is advocated often. Both of these methods have been tested thoroughly and found of little or no value. In the first place most of the moths caught are males, or females which have deposited their full quota of eggs, and in the second place a great many beneficial insects which prey upon the bollworm in different stages are destroyed. The placing of poisoned sweets in pans in the cotton field also has been found to be a useless practice.

PUBLICATIONS OF UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO INSECTS INJURIOUS TO COTTON OTHER THAN THE BOLL WEEVIL.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

The Fall Army Worm, or "Grass Worm," and Its Control. (Farmers' Bulletin 752.)

The Red Spider on Cotton and How to Control It. (Farmers' Bulletin 831.)

Carbon Disulphid as an Insecticide. (Farmers' Bulletin 799.)

How Insects Affect the Cotton Plant and Means of Combating Them. (Farmers' Bulletin 890.)

The Argentine Ant: Distribution and Control in the United States. (Department Bulletin 377.)

The Red Spider on Cotton. (Department Bulletin 416.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

Two Destructive Texas Ants. (Entomology Circular 148.) 1912. Price, 5 cents.

Cotton Stainer. (Entomology Circular 149.) 1912. Price, 5 cents.

Cotton Worm or Cotton Caterpillar. (Entomology Circular 153.) 1912. Price, 5 cents.

Report on Miscellaneous Cotton Insects in Texas. (Entomology Bulletin 57.) 1906. Price, 5 cents.

Cotton Stalk-borer. (Entomology Bulletin 63, pt. VII.) 1907. Price, 5 cents.

Mexican Conchuela in Western Texas in 1905. (Entomology Bulletin 64, pt. I.) 1907. Price, 5 cents.

Notes on Economic Importance of Sowbugs. (Entomology Bulletin 64, pt. II.) 1907. Price, 5 cents.

Plant-bugs Injurious to Cotton Bolls. (Entomology Bulletin 86.) 1910. Price, 20 cents.

Argentine Ant. (Entomology Bulletin 122.) 1913. Price, 25 cents.

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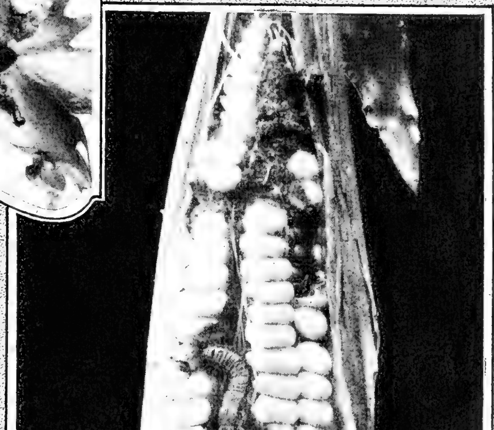
The BOLLWORM OR CORN EARWORM



THE BOLLWORM or corn earworm is an important enemy of cotton, corn, tomatoes, and tobacco. It feeds also on many other cultivated and wild plants.

As the winter is passed in the pupa or resting stage, 4 to 6 inches below the surface of the soil, late fall or winter plowing will cause the death of many pupæ. This is probably the most important of all control practices.

Since the insect increases greatly in numbers late in the season and hard bolls of cotton and ripening corn ears are largely immune to attack, it is important that these crops be matured as early as possible.

The caterpillar, except when it first hatches from the egg, feeds by boring into the fruit or stalk of the plants attacked; hence poisoning must be done at the right time to give best results. Poisoning of cotton with calcium arsenate, powdered arsenate of lead, or Paris green should take place when the corn ears in the main crop become hard; that is, about July 10 to August 20, according to latitude and season. Tomatoes may be largely protected by applications of the poison, begun as soon as injury to the plants appears and repeated at weekly intervals until 10 days before picking. Tobacco buds may be treated by dropping a teaspoonful of a mixture of arsenate of lead and corn meal into them.

Corn used as a trap crop gives some protection to cotton and tomatoes. For cotton the corn should be planted so as to come into silk and tassel when the ears of the early crop are hardening. To protect tomatoes the corn should be planted at intervals so as to be kept in silk through the greater portion of the fruiting period of the tomatoes.

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C. Issued October, 1917; revised February, 1922

THE BOLLWORM OR CORN EARWORM.[1]

By F. C. Bishopp, *Entomologist.*

CONTENTS.

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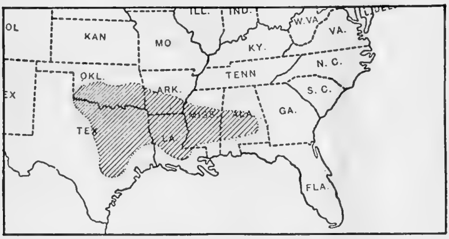

FIG. 1.—Map showing approximately the area in which the bollworm inflicts severe injury on cotton.

In the case of cotton the injury is readily distinguished from that caused by the boll weevil, as the squares and more tender bolls are completely eaten out, particularly after the worms have gained considerable size. Occasionally full-grown bolls are gnawed into by the large caterpillars and from one to all of the locks of cotton damaged. (See fig. 3.) Bolls which have become hard are seldom fed upon to any extent.

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HABITS OF THE INSECT AND HOW IT DEVELOPS.

A general knowledge of the life history and habits of an insect is needed in order intelligently to combat it. The bollworm or corn ear-

Fig. 2.—Young corn plant showing injury to growing tip by bollworm. (Quaintance.)

worm when mature (fig. 4) is a moth or miller about $1\frac{1}{2}$ inches across the spread wings. It varies in color from a light brown or olive green to pale yellow and it is commonly seen flying about in the evening. These moths feed upon nectar of various flowers and when mature they deposit from nearly 500 to almost 3,000 eggs. The eggs (fig. 5) are laid on various parts of the plant and to some extent upon weeds and upon the ground. They are white or yellowish in color, oval, and covered with minute ridges running from top to bottom and still smaller ridges across these. They are large enough to be seen readily with the naked eye. The eggs hatch in from $2\frac{1}{2}$ to 8 days or even longer, depending upon the temperature.

FIG. 3.—Cotton boll with full-grown bollworm eating into tip. Natural size. (Quaintance.)

When first hatched the larvæ or caterpillars are extremely small. They feed here and there on the surface of the plant near where the eggs were laid, but gradually work toward some tender portion within which they can bore. Growth is rather rapid, being completed in about 20 days. The larvæ shed their skins four or five times during this period. When full grown they are about $1\frac{1}{2}$ inches in length. The color varies from pale green to almost black. During the last few days of the life of the caterpillar it is capable of consuming large quantities of food, and it is during this period that it is most destructive.

When fully fed the larvæ leave the plant and burrow into the ground, where they form a kind of cell in which they transform into chrysalides or pupæ of a mahogany brown color. (See fig. 6.) They remain in this quiescent stage for about two weeks except in the case of the last brood in the fall, which stays in the ground until warm weather the following spring. The depth at which these cells are formed by the larvæ in summer varies from 1 to 4 inches according to the hardness of the soil. The overwintering pupæ are formed at somewhat greater depths, usually 4 to 6 inches. These chrysalides or pupæ produce moths which in turn lay eggs, thus completing the entire life cycle in about 30 days during warm weather.

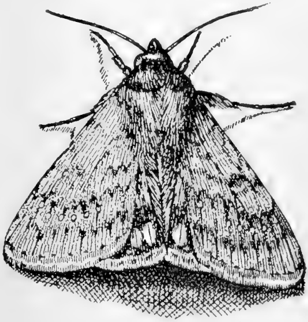

FIG. 4.—Bollworm moth with wings folded in natural position. About twice natural size. (Quaintance.)

That there is a definite connection between weather conditions and injury to the cotton crop by this insect is generally recognized. Cloudy and rainy weather during the latter part of July and throughout August undoubtedly is conducive to severe injury. This is partially explained by the moistening of the soil, which permits the moths to emerge without difficulty, and by the stimulating effect of the moisture on the growth of stalks and leaves of cotton at this time, which favors bollworm development. Furthermore, it has been found that the prevalence of such weather conditions lessens the effectiveness of certain minute parasites which prey upon the bollworm in the egg and larva stages.

SEASONAL HISTORY AND RELATION OF ABUNDANCE TO CROP GROWTH.

As has been stated, the bollworm or corn earworm pupa passes the winter months in the soil. Early in the spring the moths begin to come out, and by the time corn is "knee high" they are ready to deposit eggs. On account of the number of pupæ which die from adverse conditions in the winter, the first generation usually is small and the damage is not so appreciable. The second generation appears about the time the corn is in silk and tassel, and the number of moths is increased greatly. The caterpillars reach their full development about the time the ears of early corn become hard. In the South the third generation is the one which is destructive to cotton, the corn at this time being for the most part hard and dry. In the North this generation develops on late corn and other crops, and under usual weather conditions is the last of the season, while in the South four or even five generations may develop during a year. The late caterpillars feed on various green crops, including late cotton, cow-

FIG. 5.—Egg of bollworm moth, side and top views. Highly magnified. (Quaintance and Brues.)

peas, and alfalfa. Thus in the Southern States most of the overwintering insects will be found in soil where cotton and other late-growing crops are raised, while in the North the late cornfields probably contain most of them.

The bollworm shows a preference for corn when this crop is "silking," and this fact can be utilized to some extent in protecting cotton and other crops from injury, as will be pointed out later. These caterpillars are cannibalistic, and when they come in contact with one another many of them are killed, which usually reduces the number of worms developing in a single year to one, two, or at most three, whereas dozens of eggs may be laid upon a single strand of corn silk.

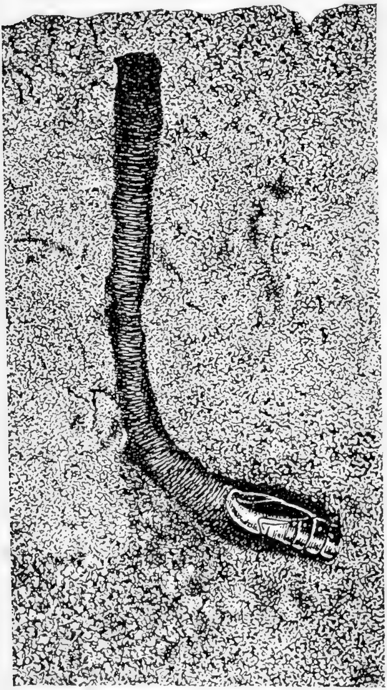

FIG. 6.—Vertical section through soil, showing pupa of bollworm in its burrow. About natural size. (Redrawn from Quaintance and Brues.)

CONTROL MEASURES.

As a result of the study of the life history and the seasonal history of this insect it will be seen that there are four outstanding facts which can be made use of in control work:

First, the insects spend the winter in the pupa stage in the ground. They also spend some time between generations in the soil. This enables the farmer to destroy many of them by plowing at the proper time.

Second, the caterpillars feed for a time on the surface of the leaves before penetrating the tissues of the plant. This is the only time during which the insect can be poisoned successfully.

Third, the number of bollworms or earworms increases greatly as the season advances. This indicates a need for hastening the maturity of all crops affected.

Fourth, since green corn is preferred as food, it is possible to utilize this to some extent as a trap to protect cotton and other crops.

It has been found that by modifying slightly the usual farm practices much can be done toward lessening bollworm or corn earworm injury. Fortunately these modifications are such as to increase crop production, regardless of the presence of this insect. Another important point is that some of the recommendations for controlling this insect are equally applicable, irrespective of the crop grown.

FALL AND WINTER PLOWING.

Probably the most important single step in controlling the bollworm consists of thorough breaking of the land in which the worms have buried themselves for the winter, at some time during the late fall or winter months. Particular attention should be paid in this respect to the crops which are known to have bollworms developing during the late fall months. The practice of fall and winter plowing, aside from bollworm control, is desirable because it conserves moisture, puts the ground in better condition for planting, and enables the farmer to plant at the proper time the following spring.

It has been found that the breaking up of the cells in which the insect is spending the winter results in the destruction of practically every pupa through the action of cold and moisture. Since the cells of the wintering brood are formed at from 4 to 6 inches beneath the surface, it is important that the plowing be deep enough to reach them. It is desirable to plow or deeply disk the fence rows and other places where bollworms may have fed on various plants. This is also beneficial in destroying eggs of grasshoppers and hibernating places of chinch bugs and other destructive insects.

CONTROL ON CORN.

CULTURAL METHODS.

In addition to the employment of fall and winter plowing, the injury to corn can be reduced somewhat by planting as early in the spring as is compatible with getting the ground into good condition. The corn should be as nearly uniform in age as possible and every effort should be made to hasten growth and maturity. Keeping the crop free from weeds and grass during the growing season not only tends to increase the yield but also destroys hiding places of the moths.

POISONING CORN.

Unfortunately no very satisfactory method of poisoning the worms on corn has been devised. As many as 50 per cent may be destroyed, but the remainder will gain entrance to the ears and produce the usual injury. Recent work conducted in Kansas by Mr. J. W. McCulloch and in Missouri by Mr. Leonard Haseman indicates that the application of powdered arsenate of lead to the silks as soon as they begin to appear will reduce the injury considerably. Owing to the rapid growth of the silk and the fact that the eggs are deposited continuously, it is necessary to make a light application of poison at three or four day intervals to secure good results. In the experiments mentioned the poison was blown onto the ears with a dust gun or applied by hand with a cheesecloth bag. The cost of application and material probably would more than offset the advantage gained under field conditions, and this method will be more applicable in protecting sweet corn or corn grown especially for roasting ears, and in reducing the amount of injury to special selections grown for seed purposes.

CONTROL ON COTTON.

CULTURAL PRACTICES.

Several of the measures best calculated to reduce bollworm injury in the cotton-growing States are equally effective in checking the ravages of the boll weevil. No loss of money or energy results from putting such cultural practices into effect, even though the bollworm should not appear in very destructive numbers in any particular year.

To protect cotton from bollworm injury it is important (1) that early maturing seed be selected; (2) that the crop be planted as early as is consistent with getting a good stand and having the crop start off well; (3) that poor lands be fertilized and cultivation be thorough and frequent. Every step should be taken which will hasten the early maturity of fruit and keep the plants in a healthy, growing condition. The reason for this can be seen readily when we know that the bollworms pass to the cotton when the corn becomes mature, and that hard bolls are not subject to injury. Since the moths hide in the foliage when the growth is luxuriant, those varieties which make comparatively small stalk without a superabundance of leaves are desirable. This also hastens the drying out of the bolls after they are grown. The early and complete destruction of cotton stalks as recommended for the boll weevil will prevent the maturity of many late bollworms and destroy a considerable number outright.

POISONING COTTON.

The use of poisons against the bollworm has met with considerable success when the poisons have been applied at the proper time. Attention has been directed to the fact that a large proportion (from 60 to 80 per cent) of the eggs deposited in cotton fields are placed elsewhere than on the squares and flowers. Following hatching, therefore, it is necessary for the young larvæ to travel a considerable distance before penetrating the fruit. During this rather aimless wandering the insect eats here and there from the surface of the leaves and stalks. During this short period in the existence of the larva it is susceptible to the action of various arsenical poisons.

The importance is emphasized of getting the poison on the plants when the numerous young larvæ of the August generation begin to hatch and not after the larvæ have grown to considerable size. In the later stages they are largely protected from the poison by their habit of burrowing into the squares and bolls and not feeding on the surface where the poison is deposited.

The time for applying the poison to cotton varies slightly from year to year. The first application should be made when the corn ears are becoming hard. The actual date will range from about July 10 to August 20, according to latitude and seasonal conditions. Close examination of the cotton plants at this time will show the earliest hatched bollworms making minute holes into squares. Often their presence may be detected by the delicate webs which the young worms sometimes spin about the squares.

Calcium arsenate, powdered arsenate of lead, or Paris green may be used for poisoning, but since the department is advocating the use of calcium arsenate against the boll weevil and since that product is being prepared especially by chemical companies for use on cotton it is to be recommended above the others. It has an advantage over Paris green in not burning the cotton plants and in being less dangerous to apply. It is more poisonous to insects than arsenate of lead and is much cheaper.

While it is possible to apply poison to cotton in the form of a spray (Paris green 1 pound, water 50 gallons), this method is usually impractical, and dust applications are advised. If Paris green is used it is best to mix it thoroughly with some carrier such as air-slaked lime at the rate of 1 pound to 3 of the carrier and make application at the rate of 6 to 9 pounds of the mixture per acre, according to the size of the plants. In using calcium arsenate from 4 to 5 *pounds without any diluent* should be applied per acre.

As the use of calcium arsenate as an insecticide is comparatively new and as there is some difficulty connected with the making of a satisfactory product it is advised that those ordering this material for use against the bollworm should call for a product having the specifications given by Mr. B. R. Coad, of the Bureau of Entomology, for use against the boll weevil. These are as follows:

Arsenic pentoxid, not less than 40 per cent.
Water-soluble arsenic pentoxid, not more than 0.75 per cent.
Density not less than 80 or more than 100 cubic inches per pound.

This gives a very light fluffy powder which forms an excellent dust if blown on the cotton with force.

The method of application should depend on the acreage to be treated. For poisoning small areas up to about 25 acres hand dust guns which are on the market may be used. About 3 acres a day can be covered with one of these. For larger acreages wheel-traction dusters are obtainable and for very large areas power blowers may be advisable.[1]

Some may prefer the old-fashioned method of applying poison with a bag and pole. This method lacks thoroughness and while satisfactory for controlling the leafworm it does not give best results against the bollworm. This equipment may be carried across the back of a mule, the poison being jarred out through the bags by movements of the animal and by tapping the pole. The construction of one of these outfits is very simple. Rectangular bags of 8-ounce duck are nailed to either end of a 4-inch board of a length equal to the distance between two cotton rows, as is shown in figure 7.

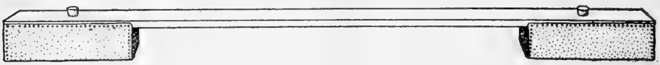

FIG. 7.—"Bag and pole" for use in distributing poison in bollworm control.

To get best results the dusting should be done when the plants are covered with dew. This necessitates making the application during the night or in the early morning hours. Windy periods should be avoided.

It should be remembered that all of these arsenicals are poisonous to man and animals although they are not dangerous if properly handled. Calcium arsenate is less injurious to man than Paris green. Men employed in distributing the poison should change their clothes and bathe immediately after ceasing work. No case of poisoning of animals used in drawing the machines has been observed, but if they are inclined to eat the cotton plants it is best to safeguard them by using muzzles.

The number of applications should depend largely on the abundance of eggs deposited during the few weeks following the first application. Some years the bollworms appear in great numbers at one time while in other seasons they are more or less distributed through the late summer. On the average it is believed that two applications of poison 7 to 10 days apart will give best results. If a heavy rain should follow within 24 hours after an application another treatment should be given. After the poison is well dried on with the dew it will withstand considerable rain.

[1] For discussion of dusting machinery for boll-weevil control see Farmers' Bulletin 1098.

In rather extensive experiments an average return of $5.21 per acre over the cost of poison and expense of application resulted. Some of the fields were treated once and others received two applications.

In sections where poisoning for the boll weevil[1] is practiced, ordinarily a high degree of control of the bollworm should result. In sections where the boll weevil and bollworm are both frequently bad an attempt should be made to follow the infestations in the fields closely enough to make applications of the poison at the proper time to check the ravages of both of these pests.

On account of the sporadic occurrence of bollworms in great numbers in most regions it is rather difficult to foresee just when serious injury is to occur, but it would no doubt be profitable to apply poison each year in the portions of Texas and Oklahoma where bollworm damage is general and more severe.

CORN AS A TRAP CROP TO PROTECT COTTON.

Since the bollworm prefers corn to cotton or most other plants for food it is possible to concentrate the larvæ on corn and keep them from becoming so numerous on cotton. To effect such a result it is important that corn be planted at such a time as to be in silk and tassel about the 1st of August. If it matures too early it will act only as a breeding place for bollworms, which will mature as the ears harden and a short time later transform to moths which in turn will deposit eggs over adjacent cotton fields. On the other hand, if the plants are in an attractive state, the moths, which fly quite freely, will assemble in the corn from considerable distances and deposit most of their eggs on the corn plants. These eggs will hatch and the young larvæ, being so numerous, will destroy one another to such an extent that usually not more than a few out of the many hatching on the silk of each ear will reach maturity.

One plan of planting the trap rows consists of leaving belts from 10 to 40 feet wide across the field at the time the cotton is planted and about June 1 planting this space with Mexican June corn in rows 5 or 6 feet apart. About 10 days later a row of cowpeas may be planted between the corn rows, thus leaving room for cultivation and at the same time furnishing attractive places for the bollworm moths, which will concentrate in the trap rows in great numbers. While any variety of corn may be used, the Mexican June corn is more desirable in the Southwest on account of its resistance to drought.

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[1] The poisoning of the boll weevil is discussed in Bulletin 875 and Department Circular 162 of the United States Department of Agriculture and in Farmers' Bulletin 1262.

Another system is to plant patches of June corn and cowpeas here and there over the plantation following such crops as oats, wheat, and potatoes. This provides a trap crop for the bollworm, results often in a good yield of corn, and in a crop of cowpeas, which is valuable as green manure or for food and forage.

CONTROL ON TOMATOES.

The worms usually begin attacking the tomato crop before the fruit is set and continue their work until frost. At first they feed on the tender leaves at the tips and burrow into the stems. Later they attack the buds and flowers, then the small fruits, and continue the damage even when the fruit is ripening.

The feeding habits of the larvæ early in the season render the use of arsenical poisons effective, and as the worms pass from one fruit to another poison will destroy many of them later, but it is not advisable to use poisons later than 10 days before harvesting begins. As the first clusters of tomatoes are of greatest value, especially in the trucking regions of the South, the early use of poisons where bollworms cause trouble undoubtedly would net good returns.

On tomato lead arsenate should be used rather than Paris green in order to prevent burning. This material may be applied in dust form or as a spray. For the spray about 2 pounds of the lead arsenate in the paste form or 1 pound of zinc arsenite dissolved in 50 gallons of water should be used per acre. The use of about 3 pounds per acre of calcium arsenate or powdered arsenate of lead applied as a dust is recommended. The first application should be made as soon as the moths are observed in the field or injury to the leaves and stalks is noticed, and succeeding treatments should follow at about weekly intervals. If fungicides (such as Bordeaux mixture) are used against diseases of the tomato, the arsenical may be added to these.

While some are averse to using poisons on crops of this kind, no injurious effects are likely to occur, especially if the applications are discontinued some time before picking begins. The early treatments are most effective, as at this time the worms are not feeding within the large tomatoes and are thus most easily reached.

CORN AS A TRAP CROP TO PROTECT TOMATOES.

The principle of trapping described for the protection of cotton can be utilized in controlling the bollworm on tomatoes. It is advisable, however, to modify it somewhat. As the moths deposit eggs on the plants during a considerable period, it is desirable to have corn in silk and tassel from the time the fruit begins to set on the tomatoes until harvesting is over. It is advisable to use small areas immediately adjacent to tomato patches and plant portions of these at two-week intervals, thus bringing a succession of plants into silking during the fruiting period of the tomato. If a large acreage is in tomatoes, it is advisable to plant a few strips of corn through the field in addition to those on the margins. As the ears become sufficiently mature for roasting they should be gathered to prevent the escape of the worms. If these worms are allowed to leave the ears in the fields, they will produce moths which in turn may cause an infestation of the tomatoes. Either field corn or sweet corn may be used as a trap crop under these conditions.

CARE OF INFESTED FRUIT.

The poison treatment should be supplemented by picking and destroying all wormy tomatoes. These should not be left in the field, as the worms will emerge from them and return to the plants or produce moths which will multiply greatly the number of the worms later in the season.

CONTROL ON TOBACCO.

A number of authorities state that where the false budworm [1] is injurious to tobacco, notably in Georgia and Florida, damage can be prevented largely, though at a considerable expense, by sifting by hand into the bud a mixture of powdered arsenate of lead and corn meal. One pound of the poison is used to 75 pounds of corn meal [2] and applications to shade tobacco are made twice a week. No doubt corn can be utilized as a trap crop to some extent as recommended for the protection of tomatoes.

INEFFECTIVE METHODS OF CONTROL.

The burning of lights for the attraction of moths in fields is not uncommon in certain sections and the idea of trapping the moths by various devices is advocated often. Both of these methods have been tested thoroughly and found of little or no value. In the first place most of the moths caught are males, or females which have deposited their full quota of eggs, and in the second place a great many beneficial insects which prey upon the bollworm in different stages are destroyed. The placing of poisoned sweets in pans in the cotton field also has been found to be a useless practice.

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[1] A local name for the bollworm, *Chloridea obsoleta* Fab.

[2] Extensive experiments have been made with many carriers, but none of them have given satisfactory results except the corn meal.

PUBLICATIONS OF UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO INSECTS INJURIOUS TO COTTON OTHER THAN THE BOLL WEEVIL.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

The Fall Army Worm, or "Grass Worm," and Its Control. (Farmers' Bulletin 752.)

The Red Spider on Cotton and How to Control It. (Farmers' Bulletin 831.)

Carbon Disulphid as an Insecticide. (Farmers' Bulletin 799.)

How Insects Affect the Cotton Plant and Means of Combating Them. (Farmers' Bulletin 890.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

The Argentine Ant: Distribution and Control in the United States. (Department Bulletin 377.) 1916. Price, 5 cents.

The Red Spider on Cotton. (Department Bulletin 416.) 1917. Price, 20 cents.

Two Destructive Texas Ants. (Entomology Circular 148.) 1912. Price, 5 cents.

Cotton Stainer. (Entomology Circular 149.) 1912. Price, 5 cents.

Cotton Worm or Cotton Caterpillar. (Entomology Circular 153. 1912. Price, 5 cents.

Report on Miscellaneous Cotton Insects in Texas. (Entomology Bulletin 57.) 1906. Price, 5 cents.

Cotton Stalk-borer. Entomology Bulletin 63, pt. VII.) 1907. Price, 5 cents.

Mexican Conchuela in Western Texas in 1905. (Entomology Bulletin 64, pt. I.) 1907. Price, 5 cents.

Notes on Economic Importance of Sowbugs. (Entomology Bulletin 64, pt. II.) 1907. Price, 5 cents.

Plant-bugs Injurious to Cotton Bolls. (Entomology Bulletin 86.) 1910. Price, 20 cents.

Argentine Ant. (Entomology Bulletin 122.) 1913. Price, 25 cents.

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THE ROUGH-HEADED CORN STALK-BEETLE IN THE SOUTHERN STATES AND ITS CONTROL

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Entomological Assistants
Cereal and Forage Insect Investigations

FARMERS' BULLETIN 875

UNITED STATES DEPARTMENT OF AGRICULTURE

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

Washington, D. C. October, 1917

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THE ADULT of the rough-headed corn stalk-beetle is responsible for all the injury done to corn by this insect. The grubs live in old, poorly drained pasture land. Therefore, do not plant corn on such lands the first year after they have been broken up.

Plant corn early, by April 20 for tidewater Virginia, and earlier for more southerly States.

Sod land intended for corn should be plowed the last of August or the first of September the summer before planting, to destroy the pupæ of the beetles.

Apply barnyard manure or commercial fertilizers in liberal quantities whenever practicable.

Drain thoroughly all low waste or pasture lands in the vicinity of corn crops.

THE ROUGH-HEADED CORN STALK-BEETLE[1] IN THE SOUTHERN STATES AND ITS CONTROL.

CONTENTS.

WITHIN recent years an increasing number of reports of serious damage to the corn crop by a robust black beetle have been received from most of the Southern States. A noteworthy outbreak occurred during the early summer of 1914 in the tidewater section of Virginia.

As very little was known regarding the natural history of this pest, this bulletin has been designed to supply this information. By following the control measures recommended herein it is hoped that the ravages of this pest may be largely overcome in the future.

FIG. 1.—Rough-headed corn stalk-beetle: Adult. Somewhat enlarged.

DESCRIPTION OF THE BEETLE.

The beetle (fig. 1) varies somewhat in size, but usually measures about one-half inch in length. It is a stout, hard-shelled creature, jet black in color. The head and fore part of the body (thorax) appear almost smooth, but the head is in reality finely roughened, and the thorax is covered with numerous minute dots or impressions. The hind body (abdomen) is covered by a pair of hard wing cases which, like the thorax, bear numerous minutely impressed dots or dents and in addition a number of faintly impressed longitudinal lines. The legs are very strong and are provided with a number of coarse spines.

DISTRIBUTION.

The distribution of the beetle, as recorded by the Bureau of Entomology, is shown on the accompanying map (fig. 2). The insect is confined entirely to the Southern States. No records of its occurrence are known north of Virginia, Kentucky, and Kansas. In

[1] (*Ligyrus*) *Euetheola rugiceps* Lec.; order Coleoptera, family Scarabaeidae.

Virginia it appears to be limited to poorly drained lands in the eastern section of the State—that is, in the section locally known as tidewater Virginia.

ECONOMIC IMPORTANCE.

The outbreak in 1914 involved, so far as can be ascertained, about 300 acres of corn (fig. 3) in the tidewater section of Virginia. The injury, as previously stated, was confined to low, poorly drained fields. Some of the infested fields were replanted as many as three times. During the spring of 1917 many reports of injury to corn by the rough-headed corn stalk-beetle were received from Texas, Georgia, Louisiana, Arkansas, and Alabama, the damage caused by the insect in these States having been severe and quite general in character wherever the nature of the soil was such as to sustain the grubs. Field observations show that these severe outbreaks, for reasons as yet imperfectly understood, do not necessarily recur in successive years.

FIG. 2.—Map showing localities where outbreaks of the rough-headed corn stalk-beetle have occurred.

MANNER OF INJURY.

It should be understood clearly that injury to corn by the rough-headed corn stalk-beetle is due entirely to the adult beetle, as the grub does not attack growing plants. The damage to the corn crop takes place only during spring and early summer. The heaviest damage in Virginia appears to occur between May 20 and June 15, although some slight injury may occur as late as the 1st of July. The beetles begin to attack the crop as soon as the plants appear above ground and continue their attacks until the plants are at least knee-high, or even somewhat taller. Full-grown plants, however, apparently are never injured. The beetle bores into the outer wall of the stalk immediately below the surface of the ground, making a large, ragged opening (fig. 4), and destroys the tender growing point or "heart," upon which the black corn beetle appears to feed especially. The destruction of the "heart," or "bud," is indicated quickly above ground by the withering of the central roll of leaves, the other leaves retaining their freshness for a considerably longer period. The roll of wilted leaves soon dies and can be pulled out with little effort.

FIG. 3.—Field of corn showing severe injury by the rough-headed corn stalk-beetle.

By the time the corn is 3 feet tall the tender growing part of the plant has been pushed above the level of the ground and is reached rarely by the beetles. Consequently, the damage to the plants at this stage is not so severe as in younger stages and the plants recover more readily from the injury.

FIG. 4.—Young corn plant, showing characteristic injury by the rough-headed corn stalk-beetle.

SEASONAL HISTORY

The rough-headed corn stalk-beetle, in common with certain other insects, has four stages in its life cycle, namely, the egg, the grub or larva, the pupa or resting stage, and the adult or beetle stage, the last, as stated, being responsible for the injury to growing corn plants.

The essential facts in the life history are briefly as follows: The eggs (fig. 5) are laid in the early summer, chiefly during the month of June, and are deposited singly or in groups of three or four in the ground wherever the beetles happen to be feeding. The egg hatches in about two weeks into a small white grub or larva (fig. 6) which often is known locally in the South as a "rich-worm." The grubs are common in midsummer and grow very rapidly, reaching full growth in about two months (fig. 7). When mature the grub changes into the pupa (fig. 8), which does not feed and is unable to move about. In about two weeks the skin of the pupa splits, is cast off, and the fully developed beetle (fig. 1) emerges therefrom. The beetles of this new generation appear about the middle of September and soon go into hibernation, there being one generation a year. It is this hibernating or wintering-over generation of beetles that injures corn in the spring.

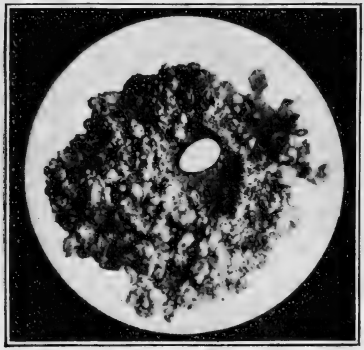

FIG. 5.—Section of earthern cell containing an egg of the rough-headed corn stalk-beetle. Considerably enlarged.

THE EGG.

The egg (fig. 5) when first deposited is about the size of the head of an ordinary pin, resembling a hen's egg in shape, and is pearly white and perfectly smooth. It increases in both weight and bulk and just before hatching it is almost round and about twice its original size.

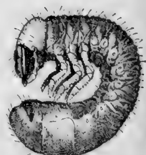

FIG. 6.—The rough-headed corn stalk-beetle: Young larva, or grub. Enlarged.

THE GRUB.

When newly hatched (fig. 6) the grub is about three-sixteenths of an inch in length. When full grown (fig. 7) it is about $1\frac{1}{4}$ inches long and about one-fourth of an inch thick. Normally it curls itself up in the form of a crescent, with the head almost touching the tail. The head is brick red and the body dirty white, being distinctly darker near the tail end. The legs are pale brown.

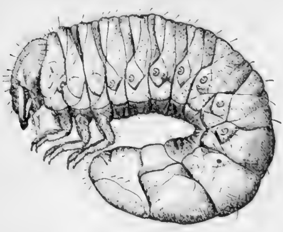

FIG. 7.—The rough-headed corn stalk-beetle: Full-grown larva, or grub. Enlarged.

The grub, so far as known, does not feed upon any of the cultivated crops but lives upon decaying vegetable matter found in or on the ground.

THE PUPA.

The pupa (fig. 8) is about three-fourths of an inch long by three-eighths of an inch broad. When it first becomes a pupa it is white but gradually changes to pale brown. During this stage the insect does not feed and is incapable of locomotion and remains throughout its existence in one place in the soil, anywhere from an inch to several inches below the surface. In this stage the insect is destroyed easily by cultivating the soil and exposing the pupæ to the sun and the attacks of birds, poultry, or hogs.

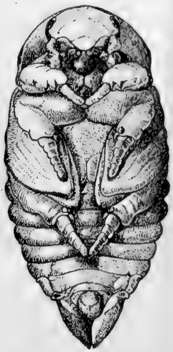
FIG. 8.—The rough-headed corn stalk-beetle: Pupa. Enlarged.

THE ADULT.

The beetle (see title page and fig. 1) develops within the pupa and when fully formed ruptures the old pupal skin and crawls forth. At first it is almost white, but gradually changes to an intense black. The majority of the beetles emerge during the month of September.

During the fall the beetles spend most of their time in the ground, but on warm days come to the surface to feed. At this time they do not molest corn, but subsist on certain wild grasses which grow abundantly in old pastures and waste areas. With the advent of cold weather the beetles pass into a condition of torpor called hibernation, during which they remain inactive in the ground. With the reappearance of warm weather in late April or early May they become active once more. If food be present, the beetles in most instances remain near the place where they had passed the winter, but when this is lacking they come to the surface and crawl or fly away in search of a more promising spot. About this time the young corn is beginning to appear above ground and the beetles, which either have passed the winter in the field itself or perhaps merely wandered into it from some other field where food was scarce, soon discover and attack the young plants. As the season progresses and the temperature rises the beetles become more active and their appetites are correspondingly more difficult to satisfy. Mating takes place below the surface of the ground and the eggs are laid shortly after. Thus the life cycle starts once more. The old beetles continue active until about the middle of June, after which they disappear quickly.

CONDITIONS FAVORABLE TO OUTBREAKS.

The natural home of the rough-headed corn stalk-beetle consists of low, poorly drained open fields which have not been cultivated for a long time. These old sod lands are utilized frequently as pastures. Whenever such lands are plowed and immediately planted to corn, the crop may suffer serious injury from the beetles which had been breeding regularly in the old sod. Then, too, in case corn is planted in near-by fields, many of the beetles are likely to spread into these from their ordinary breeding grounds. Such old sod lands support a vegetation in which certain grasses[1] flourish of which the beetles appear to be very fond. In such lands dead and decaying vegetable matter accumulates in considerable quantities, and as the grubs of the rough-headed corn stalk-beetle feed upon such substances it can be understood easily that these old sod lands afford ideal conditions for the multiplication of the pest.

Sometimes the rough-headed corn stalk-beetle appears to be able to breed in temporary sod lands, although the number of beetles produced in such pastures is far below the number which are capable of developing in an equal area of old waste land.

Cornfields appear to be very unfavorable places for the reproduction of the rough-headed corn stalk-beetle. Eggs may be found in abundance in cornfields in which the beetles are feeding, but the number of beetles which develop from these eggs is insignificant compared with the vast numbers that originate in old sod lands.

Thus it becomes evident that one of the most promising methods for controlling the beetles is to avoid maintaining pastures for indefinite periods or allowing any part of the farm to grow up as waste land.

CONTROL MEASURES.

By far the most important means of control is the elimination of all old waste and pasture lands. As has been stated previously, the favorite breeding place—and, in fact, under most conditions the only place where the pest is able to maintain itself in sufficient numbers to become a menace to the corn crops—is in low, poorly drained land that is allowed to remain as waste or as pasture lands for a considerable period of time. Land that is kept in a high state of cultivation and where frequent and systematic rotation of crops is practiced is not a favorable place for the breeding of this beetle. Therefore all low, moist areas should be drained thoroughly and included in the regular system of rotation as practiced for the remainder of the farm. This not only will destroy the main breeding grounds of the insect but will make these lowlands more productive and much easier to cultivate. *Such pasture lands should not be planted to corn the first year*, and as no other cultivated crops are injured by the rough-headed corn stalk-beetle some other crop can be substituted.

[1] *Paspalum* spp.

But since there is a single generation of the beetles a year, the ground may be planted safely to corn the following year.

PASTURING WITH HOGS.

When old waste land can not be drained conveniently and included in the regular rotation, the probabilities of injury resulting from the presence of these breeding grounds may be eliminated largely by pasturing hogs on such land every year, at least during the months of August and September. It is a well-known fact that hogs are very fond of grubs and will root them out industriously and devour them.

EARLY PLANTING.

Since the major portion of the injury to corn occurs during the latter part of May to the middle of June, and since young plants succumb to attack much more easily than larger ones, early planting is recommended where practicable, as a means of avoiding injury. It has been found that corn planted on April 25 at Tappahannock, Va., suffered much less injury from the rough-headed corn stalk-beetle than did plantings made in May. One of the most serious objections to planting so early is that lowlands often are too wet for working in early spring. This can be overcome largely by draining such lands thoroughly.

When planting early, more kernels should be planted to the hill and the plants subsequently thinned if necessary, thereby insuring a better stand.

CHANGE OF ROTATION.

As previously stated, corn should not be planted after sod where there is the prospect of injury from the beetle. Besides the rough-headed corn stalk-beetle, sod worms and cutworms are always a source of danger to corn planted on old sod land. Therefore any system of rotation which obviates the necessity of following sod with corn helps to avoid several serious insect pests.

FERTILIZERS.

The application of barnyard manure or commercial fertilizers is beneficial, because growth is hastened and the corn plants thus enabled more quickly to reach a state where they are less likely to be injured seriously.

HAND PICKING.

Hand picking is at best only a temporary expedient and in most cases very expensive. When a field of growing corn already is infested, however, there is no other hope of relief. Children sometimes may be employed for a small sum to collect and destroy the beetles found in young corn. This work may be done principally when the corn is either being plowed or thinned.

LATE SUMMER PLOWING.

The rough-headed corn stalk-beetle enters the pupa stage during the latter part of August and it is in this stage that the beetle is most easily destroyed, the least disturbance being sufficient to kill the pupæ. For this reason, wherever possible sod lands should be plowed the last week in August or the first week in September for Virginia, but earlier than this for more southerly localities.

SUMMARY OF CONTROL MEASURES.

1. Eliminate all old pastures or waste land, especially low, moist areas, and drain such lands thoroughly.
2. Pasture hogs in waste or pasture lands that can not be conveniently drained and cropped.
3. Plant corn early, say about April 20 for tidewater Virginia, and earlier for more southerly localities.
4. Give liberal applications of barnyard manure or commercial fertilizers whenever practical.
5. Employ children or cheap labor to collect and destroy the beetles when a field first shows injury.
6. Do not allow corn to follow sod if possible to avoid it.
7. Plow sod land in late summer and early fall in order to destroy the pupæ of the rough-headed corn stalk-beetle.

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FUMIGATION OF ORNAMENTAL GREENHOUSE PLANTS WITH HYDROCYANIC-ACID GAS

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L. O. HOWARD, Chief

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BY THE CAREFUL use of hydrocyanic-acid gas in accordance with the directions given in this bulletin practically all insects infesting the foliage of ornamental plants in greenhouses may be controlled, and more cheaply and effectively than by any other means.

In fumigating a house containing a large variety of plants, using the correct dosage and under proper conditions, the tender growth of some plants may be injured. This injury is not permanent, however, and such plants will show new vigorous growth in a short time. Moreover, the growth of many plants is stimulated by hydrocyanic-acid gas.

Chemicals required in fumigating with hydrocyanic-acid gas are sodium cyanid containing not less than 51 per cent cyanogen (or potassium cyanid containing not less than 38.4 per cent cyanogen), sulphuric acid 93 per cent pure, and water. Cyanid for fumigation purposes should be practically free from chlorin.

Fumigation should not be undertaken in daylight or when the temperature in the greenhouse is below 52° F. or above 70° F.

Cyanid is one of the most poisonous substances known. Care should be taken to observe the precautions stated on pages 11 and 12.

FUMIGATION OF ORNAMENTAL GREENHOUSE PLANTS WITH HYDROCYANIC-ACID GAS.

CONTENTS.

Hydrocyanic-acid gas, if intelligently employed, is one of the cheapest and most efficient methods of controlling thrips, aphids, white flies, and various scale insects on plants grown under glass. This method of control, however, has not been adopted generally because of the deadly poisonous nature of the gas if inhaled, its disastrous effect on tender plants if improperly used, and the prevailing impression that fumigation is a cumbersome procedure requiring considerable skill on the part of the operator. It is true that much damage to the plants and injury to the operator may result from the *careless* use of hydrocyanic-acid gas, but it is an established fact also that this fumigant in competent hands is a safe, practical, and economical means of controlling virtually all insect pests found in greenhouses.

EQUIPMENT NECESSARY FOR FUMIGATION.

GENERATORS.

One-half-gallon or one-gallon glazed earthenware jars serve as satisfactory generators, although it is preferable that the bottoms of the jars be rounded inside, so that the cyanid will be covered with the acid and water, even with small doses, thus insuring the maximum generation of the gas.

CAUTION.—*Hydrocyanic-acid gas is colorless and is one of the most deadly poisonous gases known. It has an odor much like that of peach pits. In case of accidental inhalation of the gas, the person affected should be kept in the open air and required to walk to increase respiration.*

Crocks with straight sides are frequently sold with glazed earthenware tops. These tops or covers increase the cost of the generators and, furthermore, are useless for fumigation purposes. Therefore, when generators are ordered it should be indicated that tops are not desired.

MISCELLANEOUS REQUIREMENTS.

Correct scales or balances, reading in tenths of an ounce, are convenient for accurate work. An 8-ounce graduate is desirable for measuring the acid and water. To avoid splashing of the acid it should not be poured from a carboy or bottle into the graduate but should be transferred to a porcelain pitcher, from which it may be poured with safety. It is well to have on hand a supply of small bags in which to place the cyanid.

PREPARATION OF GREENHOUSE FOR FUMIGATION.

As a preliminary to fumigating the greenhouse it is essential that the exposed glass surface be examined carefully and all broken glass replaced. All cracks should be closed thoroughly. The ventilators—both side and top, where possible—should be so arranged that they can be opened from the outside of the greenhouse upon the completion of the exposure. This can be accomplished by disconnecting the "machine," or gear, of the top ventilators and attaching to the central ventilator shaft (see figs. 1 and 4) an arm (*a* or *b*) which can be controlled by a cord or wire which extends through the side of the greenhouse. The gears on the side ventilators may be disconnected so that the sash may be opened from the outside. If only one ventilator can be opened, it is preferable that it be the one on the roof of the greenhouse.

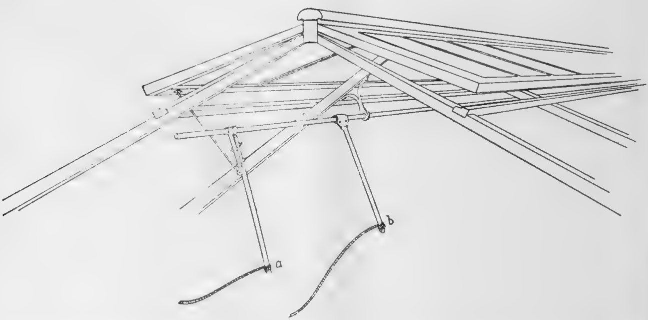

FIG. 1.—Methods of attaching rod and cord (*a*, *b*) to ventilator shaft of greenhouse so that the ventilators can be opened from the outside after fumigation.

METHOD OF COMPUTING THE CUBICAL CONTENTS OF EVEN AND THREE-QUARTER SPAN GREENHOUSES.

It is essential in every instance that the cubical contents of the greenhouse to be fumigated be determined accurately, and the following is a simple method of arriving at these figures: To facilitate matters a diagram indicating the necessary dimensions of the greenhouse should be made. (See figs. 2 and 3.)

To secure the cubical contents of the even-span greenhouse (fig. 2), compute the number of square feet in the rectangle *a* and in the right-angle triangles *b* and *c* and multiply the sum of the three by the length of the greenhouse. For example, $a=5\times20=100$ square feet; $b=5\times10\div2=25$ square feet;[1] and $c=5\times10\div2=25$ square feet. $a+b+c=150$ square feet. 150 square feet $\times$ 100 feet (length of house) = 15,000 cubic feet, cubical contents of the greenhouse.

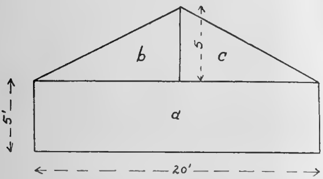

FIG. 2.—Diagram showing method of computing cubical contents of even-span greenhouse.

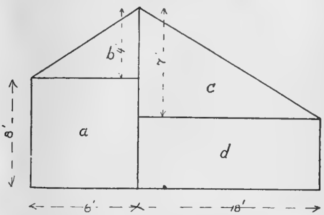

FIG. 3.—Diagram showing method of computing cubical contents of three-quarter-span greenhouse.

To secure the cubical contents of the three-quarter-span greenhouse (fig. 3), multiply the sum of the rectangles *a* and *d* and right-angle triangles *b* and *c* by the length. For example $a=6\times8=48$ square feet; $d=18\times5=90$ square feet; $b=6\times4\div2=12$ square feet; and $c=18\times7\div2=63$ square feet. $a+d+b+c=213$ square feet. 213 square feet $\times$ 100 feet (length of house) = 21,300 cubic feet, cubical contents of greenhouse.

In estimating the cubical contents of a greenhouse it is not necessary to make allowances for the space occupied by the benches, pots, etc.

TIME FOR FUMIGATION.

Fumigation should be conducted not earlier than one hour after sunset and should not be attempted when the wind is high. It is undesirable to fumigate during extremely cold nights, when the thermometer is registering near zero, owing to the necessity of ven-

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[1] To calculate the area of a right-angle triangle, multiply the base by the perpendicular and divide the product by two.

tilating the greenhouse upon the completion of an exposure. It is inadvisable to fumigate on hot, humid nights, when the temperature in the greenhouse can not be lowered readily to the desired limit. The best temperature for fumigation is between 55° and 68° F.

The interval between fumigations naturally should be governed by the reappearance of the insect under control. With small dosages, which are imperative when fumigating a greenhouse containing an assortment of plants, it is possible to kill only the larvæ of scale insects, the adults and first larva stages of the greenhouse white fly, the adults of the Florida fern caterpillar, greenhouse leaf-tyer, and loopers, and a certain percentage of aphids. The eggs and pupæ of most greenhouse insects offer considerable resistance to hydrocyanic-acid gas, and, furthermore, the overlapping of broods necessitates several fumigations at short intervals. It has been proved repeatedly that three or four fumigations at short intervals will give practical control.

CHEMICALS REQUIRED FOR FUMIGATION.

The chemicals required in fumigating with hydrocyanic-acid gas are sodium cyanid (NaCN) or potassium cyanid (KCN), sulphuric acid (H_2SO_4), and water (H_2O). Potassium cyanid has been superseded recently by sodium cyanid in the generation of this gas, and the former is rarely used nowadays in fumigation. Sodium cyanid for fumigation purposes should be practically free from chlorin and should contain not less than 51 per cent of cyanogen. It may be purchased either in lumps or in the shape of an egg, each "egg" weighing approximately 1 ounce. The latter is easily handled and the necessity of weighing each charge is obviated, provided, of course, the dosage is in ounces. For example, if the greenhouse requires 10 ounces of cyanid, 10 "eggs" are used. In small dosages, however, where the cyanid is measured in grams, it is necessary to use small lumps or break up the "eggs."

Cyanid is one of the most poisonous substances known and should be stored in air-tight cans, plainly labeled, and kept out of reach of those unacquainted with its poisonous nature.

Commercial sulphuric acid (about 1.84 sp. gr. or 66° Baumé) that is approximately 93 per cent pure is commonly used and gives very satisfactory results. The acid should be kept in a glass receptacle, properly labeled, and tightly corked with a glass stopper.

DETERMINING THE AMOUNT OF CYANID TO BE USED.

Satisfactory results are obtained only where it is possible to overcome the resisting power of the insects without overcoming the resisting power of the plant. Under favorable conditions greenhouses that do not contain roses, rose geraniums, asparagus ferns, lemon verbenas, snapdragons, wandering Jew, or sweet peas can be fumigated with safety with an initial dosage of one-half ounce of sodium cyanid (NaCN) per 1,000 cubic feet. *In case there is any doubt as to the amount of gas a plant will stand without injury, it is preferable that the initial dosage be not over one-fourth ounce of sodium cyanid per 1,000 cubic feet* and increased with subsequent fumigations until the fatal point for the pest to be controlled is reached, it being borne in mind that in some instances it is not possible to effect an absolute control of all stages of some insects with one fumigation without injury to foliage or growing parts of certain plants. For example, the greenhouse white fly can be eradicated with three successive fumigations at intervals of seven to nine days, using one-half ounce of sodium cyanid (NaCN) per 1,000 cubic feet, in houses containing such susceptible plants as coleus, ageratum, heliotrope, fuchsia, etc., with no injury to the foliage. Moreover, such resistant pests as scale insects can be eliminated entirely by killing the immature stages with a small dosage repeated at frequent intervals.

To determine the total amount of cyanid to be used, ascertain from Table II on page 13 the plants in your greenhouse which are most easily injured by the gas fumes and note the amount of cyanid which was used per 1,000 cubic feet with little or no injury to the plants. Then multiply the number of thousand cubic feet contained in the greenhouse by the amount of cyanid to be used per 1,000 cubic feet. For example, if one-half ounce of cyanid is to be used per 1,000 cubic feet, and the greenhouse contains 15,000 cubic feet, the total amount of cyanid necessary would be 7½ ounces.

In case there is any doubt as to the amount of gas the plant can stand without injury, the initial dosage, as previously stated, should not exceed one-fourth ounce per 1,000 cubic feet.

Table I gives the amount of sodium cyanid per 1,000 cubic feet needed to destroy the insect pests most commonly found in greenhouses. *Before fumigation is begun, however, Table II should be consulted for information as to the maximum dosage the particular plants can stand without injury. If this dosage is less than that indicated in Table I, complete control, of course, should not be attempted with one fumigation*

TABLE I.—*Amounts of cyanid and number of fumigations sufficient to destroy various greenhouse pests.*

Insects.	Ounces per 1,000 cubic feet.	Number of fumigations required.	Interval between fumigations.
			Days.
Aphids[1]	½	1	
Azalea lacewing	½	1	
Thrips	½	2	10.
Greenhouse white fly	½	3	7 to 9.
Long scale	¾	1	
Greenhouse Orthezia[2]	¾	2	21 to 28.
Palm mealybug[2]	2½	1	
Palm aphis	2½	1	
Long-tailed mealybug[2]	2½	2	Do.
Florida red scale	2½	2	Do.
Thread scale	2½	2	Do.
Aspidistra scale	2½	2	Do.
Soft brown scale	2½	2	Do.
Hemispherical scale	2½	2	Do.
Tessellated scale	2½	2	Do.
Florida fern caterpillar	5	1	
Citrus mealybug[2]	5	2	Do.

[1] For the most part aphids can be controlled with one-half ounce of sodium cyanid per 1,000 cubic feet, although there are a few species which are quite resistant to this gas and not so readily killed.
[2] The greenhouse Orthezia and mealybugs around the roots of plants are very difficult to kill, and this dosage is recommended only for those occurring above the soil.

CHEMICAL FORMULA TO BE EMPLOYED.

The chemicals [1] should be mixed in the following proportions: For each ounce of sodium cyanid use 1½ fluid ounces of sulphuric acid and 2 fluid ounces of water.

MIXING THE CHEMICALS.

After the generators have been distributed throughout the greenhouse, and before the chemicals have been mixed, the cyanid should be weighed accurately and the proper amount for each generator placed in a paper bag near the generator. The chemicals should be mixed invariably in the following manner: First, measure and place in each generator the amount of water required; second, measure and place in each generator the amount of sulphuric acid required; third, drop the cyanid into the diluted warm acid in each generator, immediately leave the greenhouse, and post a danger sign on the closed door. The cyanid should be dropped gently from the bag, not thrown, into the generators, and the operator should begin at the generator farthest from the door and work toward the door. In case there are two rows of generators the cyanid should be dropped simultaneously by two operators. As little time as possible should elapse between the addition of the acid and the addition of the cyanid, as the heat which is liberated by the mixing of the acid and water assists in the generation of the gas.

[1] If potassium cyanid is used in place of sodium cyanid, the formula should be as follows: For each ounce of 98 to 99 per cent potassium cyanid containing 38.4 per cent cyanogen use 1 ounce of sulphuric acid and 3 ounces of water. The yield from 1 ounce of high-grade sodium cyanid is equivalent to the yield from 1⅓ ounces of high-grade potassium cyanid.

The residue left in the generators after fumigation should be buried or poured into a sink and the generator washed before being stored for future operations.

NUMBER OF GENERATORS TO BE EMPLOYED.

The number of generators to be employed will depend largely upon the size of the greenhouse, and they should be so arranged that the gas will be distributed uniformly throughout the inclosure. To secure this advantage a number of generators should be used rather than one large generator. Generators should be spaced from 20 to 25 feet apart (see fig. 4), and in case of a light wind a few extra generators should be placed on the windward side of the greenhouse. An ounce to each jar is as small a dose as is practicable, unless the generators are well rounded inside at the base or well tilted.

EXPOSURES.

Short exposures with a greater strength of gas are more satisfactory than a weaker strength of gas overnight. In fact, better results will be gained if the exposures do not exceed one to two hours. An exposure of one hour is satisfactory in most instances. Short exposures also have the additional advantage of permitting the greenhouse to become thoroughly aired previous to the rising of the sun.

VENTILATION AFTER FUMIGATION.

If there is a light wind, a ventilation of 10 to 15 minutes, using side and top ventilation, will be sufficient and will not lower the greenhouse temperature to a dangerous point unless it is close to zero weather outside. If it is a still evening and the outside temperature is not below 32° F., a 20 to 30 minute ventilation will be satisfactory.

In case it is necessary to enter the greenhouse shortly after ventilation to determine the temperature, the person entering should not remain any longer than is necessary.

EFFECTS OF WEATHER AND OTHER CONDITIONS ON FUMIGATION.

TEMPERATURE.

It is not advisable to fumigate if the temperature in the greenhouse exceeds 70° F. or if the temperature is less than 52° F.

LIGHT.

Light unquestionably affects fumigation. It has been known for a long time that it is very unsafe to fumigate when the sun is high. Furthermore, some injury may result to plants which have been subjected to fumes if, on the following day, the sun is very bright.

MOISTURE.

Hydrocyanic-acid gas is readily soluble in water, and as a result the presence of excessive moisture in greenhouses decreases the effectiveness of the gas and consequently lessens the possibility of injury to the plants by burning. It is obvious, therefore, that in order to increase the effectiveness of the fumigation the plants should be syringed not less than four or five hours prior to the liberation of the gas, to avoid undue absorption of the gas by the water on the benches and walks.

HUMIDITY.

A relatively high humidity (98 to 100), with temperature varying from 70° to 75° F., greatly increases the amount of injury to the foliage of the plants, whereas plants in the presence of the same high humidity (98 to 100), with a temperature of 60° to 65° F., will exhibit little if any injury.

ADVISABILITY OF A FUMIGATION BOX.

A fumigation box is desirable for two reasons, namely, for testing the amount of gas plants can stand without injury, and for ridding a limited number of potted plants of insects, and thus avoiding costly and laborious hand scrubbing of such plants. The size of the box will depend on the use to which it is to be put. A box with a capacity of 200 cubic feet can be used advantageously for nursery stock, palms, etc.

Plants to be fumigated in a box in the daytime should remain in the box with the door closed at least one hour before the gas is generated and should be shaded from the bright sunlight for at least two hours after the completion of the exposure.

HOW GREENHOUSES BECOME INFESTED WITH INSECTS.

Doubtless many greenhouses become infested with insects through the agency of plants commonly referred to as "boarders." The practice of turning over home-grown plants to a florist to care for during the absence of the owner on a vacation is prevalent over the entire country, and often results in establishing pests not hitherto known to occur on the florist's premises. If the trade requires such a practice, plants of this character should be cleaned thoroughly of insect pests before being placed with the regular stock of the greenhouse.

Insect infestations in greenhouses have been traced to the following sources: Infested plants brought in from coldframes or propagating beds which have not received proper attention; cuttings, plants, and buds received from other establishments; and imported foreign or domestic stock. Adults of the greenhouse white fly, grasshoppers, beetles, aphids, etc., may enter through open ventilators from other greenhouses or gardens; cutworms, wireworms, white grubs, etc., may be brought into the greenhouse with the soil; and roaches, ants, sowbugs, millipedes, etc., are sometimes brought in with packages, or they may crawl into the greenhouse through small openings.

COST OF HYDROCYANIC-ACID GAS FUMIGATION.

The economy in the use of hydrocyanic-acid gas as a means of controlling aphids, white flies, thrips, and the common greenhouse scale insects is apparent from the following figures, which are based on current manufacturers' prices:

For the most part, aphids can be controlled with a single fumigation at the rate of one-half ounce per 1,000 cubic feet at a cost of approximately 1 cent per 1,000 cubic feet. Tobacco fumigation with standard tobacco paper costs from 1½ to 3 cents per 1,000 cubic feet, and to secure a satisfactory control the operation must be repeated several times. Standard nicotine soap solution costs from 1 to 3 cents per gallon, and 4 gallons are required to cover plants which would occupy 1,000 cubic feet of space.

The greenhouse white fly can be controlled with three successive fumigations at the rate of one-half ounce of sodium cyanid per 1,000 cubic feet, with a total cost of 3 cents per 1,000 cubic feet for a complete control. Standard insecticides cost about 6 cents per 1,000 cubic feet for a single application, and fully four applications are required for a satisfactory control.

Thrips can be controlled on such plants as azaleas, lilies, and ferns with a single fumigation at the rate of one-half ounce of sodium cyanid per 1,000 cubic feet at a cost of 1 cent per 1,000 cubic feet. A single application of nicotine soap solution costs fully five times as much as the gas treatment and still gives only a partial control.

The common scale insects of greenhouses (excepting mealybugs) can be controlled by fumigating the infested plants at the rate of three-fourths ounce of sodium cyanid per 1,000 cubic feet at a cost of 1½ cents per 1,000 cubic feet. The standard proprietary insecticides commonly recommended for scale insects cost approximately 4 cents per gallon, with an average cost of 16 cents per 1,000 cubic feet for each treatment. A 5 per cent homemade kerosene emulsion costs approximately one-half cent more per 1,000 cubic feet than does the gassing method, and gives very indifferent results.

The foregoing figures do not take into consideration the cost of labor. The time required for fumigation, however, will not exceed the time required for the mixing and application of the sprays.

PRECAUTIONS.

Do not *guess* the amount of chemicals to be employed or the cubic contents of the house.

Do not fumigate plants in a greenhouse in daylight. (For box fumigation in daytime, see page 10.)

Do not fumigate when the temperature in the greenhouse is below 52° or above 70° F.

Do not leave the chemicals within reach of those unacquainted with their poisonous nature. Always have them properly labeled.

Do not handle the chemicals any more than is absolutely necessary. It is well to have a pair of old gloves for this, and to use them for no other purpose. Always wash the hands thoroughly after handling the chemicals whether gloves have been used or not.

Do not allow the acid to splash or drop on the clothing or skin.

Do not stay in the greenhouse any longer than is necessary to place the cyanid in the jars, and *never* enter a greenhouse charged with the gas until it has been thoroughly aired.

Do not fail to post danger signs at all entrances before setting off the charge, and to see that the greenhouse is closed tightly.

Do not attempt to fumigate without adjusting the ventilators so that they can be operated from the outside.

Do not attempt to fumigate a large greenhouse alone.

Do not fumigate a greenhouse adjoining a dwelling without notifying the occupants before fumigation.

Do not pour the water on the acid; pour the acid on the water.

Do not become negligent in any of the precautions; to do so may cause serious results.

GUIDE TO GREENHOUSE FUMIGATION.

Table II is offered as a guide to those desiring to employ hydrocyanic-acid gas for controlling greenhouse pests. As indicated in this table, certain insects and plants are more resistant to hydrocyanic-acid gas than are others, and this fact should be borne in mind when a greenhouse containing a miscellaneous collection of plants is to be fumigated.

TABLE II.—*Results of fumigation with hydrocyanic-acid gas in greenhouses and boxes.*

[Plants with an * were fumigated in a box.]

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	Greenhouse temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°F.			
Abutilon sp	½	......	1	58	Greenhouse white fly.	No burning	All stages except eggs and late pupæ killed.
Do	¾	......	1	68	do	do	Do.
Acalypha sp	¾	......	1	60		do	
Achyranthes sp	¾	......	1	60		do	
Ageratum sp	½	......	1	58	Greenhouse white fly.	do	Do.
Do	5	......	1	52		Tender tips burned.	
Air plant	¾	......	1	68	Aphids	No burning	100 per cent killed.
Allamanda hendersoni	½	......	1	60		do	
Alpinia sanderae	½	......	1	62		do	
Alternanthera sp	½	......	1	60		do	
*Do	......	10	1	73		do	
Althea sp	½	......	1	60	Aphids	do	Do.
Amaranthus sp	¾	......	1	55		do	
Amaryllis sp	¾	......	1	68		do	
Anthericum comosum	½	......	1	60	Long scale	do	80 per cent killed
Do	¾	......	1	60	do	do	100 per cent killed.
Anthurium sp	½	......	1	60		do	
Ardissia sp	½	......	1	62		do	
Araucaria excelsa	½	......	1	66		do	
Aristolochia sipho	......	5	¾	66		do	
Artemisia sp	......	1½	1	73		Slight burning	
Artillery plant	½	......	1	70		No burning	
Asparagus plumosus	½	......	1	66		Tips burned	
Asparagus sprengeri	½	......	1	60		Tender tips burned.	
Aspidistra lurida	2½	......	1	62	Florida red scale	No burning	Do.
Aster	½	......	1	62		do	
Aucuba japonica	¾	......	1	68		do	
Azalea sp	5	......	1	50	Greenhouse thrips.	do	Do.
Do	½	......	1	60	do	do	Do.
Do	½	......	1	60	Azalea lacewing	do	Do.
Do	¾	......	1	60	Azalea Eriococcus.	do	50 per cent killed.
Do	......	7½	1	......		Slight burning	
Begonia sp	½	......	1	60	Greenhouse Orthezia.	No burning	70 per cent killed.
Do	5	......	1	52		do	
Berberis rehderiana	½	......	1	62		do	
Bougainvillea	¾	......	1	56		do	
Do	5	......	1	52		Foliage burned	
Buxus sp	......	7½	1	......		No burning	
Calendula	½	......	1	60		do	
Caladium	5	......	1	52		do	
Camellia japonica	5	......	1	52	Citrus mealybug.	do	100 per cent killed.
*Do	10	......	1	60		New growth burned.	
Canna	½	......	1	64		No burning	
Carnation	1	......	1	54	Greenhouse thrips.	do	Do.
*Do	5	......	1	73		Tender foliage burned.	
Centaurea	½	......	1	60	Onion thrips	No burning	95 per cent killed.
Cereus (night-blooming)	2½	......	1	63		do	
Chrysanthemums:							
Single-stem var	½	......	1	62	Aphids	do	100 per cent killed.
Do	¾	......	1	68	do	do	Do.
Pompon var	½	......	1	62	do	do	Do.
Do	1	......	1	67	do	do	Do.
Cigar plant	¾	......	1	68	do	do	Do.
Cineraria	¾	......	1	60	do	do	Do.
Clerodendron	......	5	¾	66		do	

TABLE II.—*Results of fumigation with hydrocyanic-acid gas in greenhouses and boxes*—Continued.

[Plants with an * were fumigated in a box.]

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	Greenhouse temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°F.			
Cockscomb	½	......	1	64	....	No burning	
Coleus	¾	......	1	66	Greenhouse Orthezia.	do	100 per cent killed.
Columbine	5	......	1	59	....	do	
Coreopsis	½	......	1	62	....	do	
Cosmos	½	......	1	60	....	Tips burned	
Croton	¾	......	1	56	Long scale	No burning	Do.
Do	5	......	1	52	Immature citrus mealybug.	do	Do.
*Do	10	......	¾	68	Long scale	do	Do.
Cycas circinalis	2½	......	1	63	Florida red scale.	do	Do.
Cyclamen	¾	......	1	68	....	do	
*Do	10	......	1	60	....	Flowers killed	
Daffodil	¾	......	1	55	....	No burning	
Deutzia gracilis	......	1⅘	½	......	Aphids	do	Do.
Digitalis	½	......	1	62	....	do	
Dioscorea pentaphylla	½	......	1	64	....	do	
Dracaena knerki	2½	......	1	63	Long-tailed mealybug.	do	Do.
Dracaena indivisa	......	5	¾	52	....	do	
Dusty miller	½	......	1	60	....	do	
Erica sp	½	......	1	64	....	do	
Eupatorium sp	¾	......	1	60	....	do	
Euphorbia sp	½	......	1	60	....	do	
Euonymus sp	½	......	1	60	....	do	
Ferns:							
Adiantum cuneatum	5	......	1	59	....	do	
Do	5	......	¾	62	Larvæ of Fla. fern caterpillar.	do	Do.
*Do	7½	......	¾	68	do	do	Do.
*Do	10	......	¾	68	do	New growth burned.	Do.
Adiantum croweanum	5	......	1	59	....	No burning	
Adiantum gracilium	½	......	1	57	Fern aphid	do	Do.
Adiantum trapeziforme.	½	......	1	57	do	do	Do.
Adiantum cardiocheleana.	2½	......	1	63	....	do	
Aspidium tsus-sinense	2½	......	1	59	....	do	
Asplenium nidus-avis.	¾	......	1	68	....	do	
Cyrtomium rochfordianum.	2½	......	1	59	....	do	
Cyrtomium falcatum.	¾	......	1	60	....	do	
Lastraea chrysoloba	¾	......	1	68	....	do	
Nephrolepis bostoniensis.	2½	......	1	63	Aspidistra scale.	do	Do.
*Do	5	......	¾	62	Larvæ of Fla. fern caterpillar.	do	Do.
*Do	7½	......	¾	68	do	do	Do.
*Do	10	......	1	68	do	New growth burned.	Do.
*Do	......	5	½	76	Aspidistra scale.	No burning	All stages except eggs killed.
Nephrolepis scottii	2½	......	1	59	....	do	
Nephrolepis whitmanii.	2½	......	1	59	....	do	
Do	5	......	¾	66	Larvæ of Fla. fern caterpillar.	do	100 per cent killed.
Polystichum setosum.	¾	......	1	60	....	do	
Pteris wilsoni	2½	......	1	63	....	do	
Pteris wimsetti	2½	......	1	63	....	do	
Ficus elastica	2½	......	1	59	Florida red scale	do	Do.
Ficus pandurata	2½	......	1	63	Long-tailed mealybug.	do	Do.
Ficus utilis	2½	......	1	63	....	do	
Forgetmenot	½	......	1	56	....	do	
Do	5	......	1	52	....	Tips burned	
Forsythia viridissima	......	1⅘	½	......	Aphids	No burning	Do.
Freesia	¾	......	1	60	....	do	
Fuchsia	½	......	1	60	Aphids	do	Do.

Table II.—*Results of fumigation with hydrocyanic-acid gas in greenhouses and boxes*—Continued.

[Plants with an * were fumigated in a box.]

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	Greenhouse temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°F.			
Fuchsia	½	......	1	60	Greenhouse white fly.	No burning	All stages except eggs and late pupæ killed.
Do	5	......	1	58		Tips burned	
Gaillardia sp	½	......	1	62		No burning	
Gardenia	5	......	1	60		do	
Do	......	7½	1	......		Slight burning	
Genista	¾	......	1	55	Red spider	No burning	No killing.
Do	5	......	1	52	do	Flowers and new growth burned.	100 per cent killed.
Geraniums:							
Bedding	½	......	1	60	Greenhouse white fly.	No burning	All stages except eggs and late pupæ killed.
Do	5	......	1	60		New growth burned.	
Peppermint	¾	......	1	68		No burning	
Rose	½	......	1	64		New growth burned.	
Gladiolus	¾	......	1	55		No burning	
Heather (Scotch)	¾	......	1	68		do	
Do	......	5	¾	52		Slight burning	
Heliotrope	¾	......	1	60		No burning	
Do	5	......	1	58		Tips burned	
Hibiscus sp	¾	......	1	55		No burning	
Hyacinth (Roman)	2	......	1	56		do	
Hyacinth (water)	¾	......	1	55		do	
Hydrangea	¾	......	1	60		do	
Impatiens sultani	¾	......	1	68	Aphids	do	100 per cent killed.
Ipomoea grandiflora	¾	......	1	60		Open flowers burned.	
Ivy (English)	5	......	1	48	Fla. red scale	No burning	96 per cent killed.
Ivy (German)	¾	......	1	58	Spanish red scale.	do	100 per cent killed.
Iris (Spanish)	½	......	1	64		do	
Do	......	5	¾	66		Tips burned	
Jerusalem cherry	½	......	1	60	Aphids	No burning	Do.
Lantana	½	......	1	60	Orthezia	do	90 per cent killed.
Do	¾	......	1	56		do	
Laurus nobilis	5	......	1	54	Soft brown scale. Laurel scale Long-tailed mealybug.	 No burning 	95 per cent killed. 98 per cent killed. 100 per cent killed.
Do	......	7½	1	......	Soft brown scale.	No burning	90 per cent killed.
Lillies:							
Calla	½	......	1	64		do	
Do	......	5	¾	65		do	
Lilium formosum	½	......	1	60	Aphids	do	100 per cent killed.
Do	¾	......	1	60		do	
Lilium multiflorum	½	......	1	60	Aphids	do	Do.
Do	¾	......	1	60		do	
Lilium speciosum rubrum.	½	......	1	58	Aphids	do	No killing.
Lobelia	5	......	1	59		Tips burned	
Marguerite	½	......	1	70	Aphids	No burning	100 per cent killed.
Do	½	......	1	60	Immature hemispherical scale.	do	95 per cent killed.
Do	¾	......	1	68		do	
Marigold (French)	¾	......	1	64		do	
Mignonette	½	......	1	60		do	
Do	5	......	1	52		Tips burned	
Mimulus moschatus	¾	......	1	56		No burning	
Narcissus poeticus	¾	......	1	55		do	

TABLE II.—*Results of fumigation with hydrocyanic-acid gas in greenhouses and boxes*—Continued.

[Plants with an * were fumigated in a box.]

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	Greenhouse temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°F.			
Narcissus barri	¾	......	1	55		No burning	
Nasturtium	¾	......	1	55		do	
Nigella sp	½	......	1	62	Aphids	do	100 per cent killed.
Nymphaea sp	2½	......	1	63		do	
Orchids:							
Angraecum eburneum.[1]	½	......	1	60		do	
*Do.[1]	5	......	1	62	Diaspis sp	Slight burning	Do.
Brassea verrucosa.[1]	½	......	1	57		No burning	
Calanthe (hybrid)[1]	½	......	1	58		do	
Cattleya mossiae[1]	½	......	1	60		do	
Cattleya trianae[1]	½	......	1	57	Thrips	do	All stages except eggs killed.
Cattleya trianae[2]	20	......	3	70		do	
Cattelya sp[2]	......	20	½	......		do	
Do	......	21	1	......		do	
Do	......	42	½	......		Slight burning, plant recovered.	
Chysis aurea	½	......	1	57		No burning	
*Coelia baueri	5	......	1	62		do	
Coelogyne cristata	⅓	......	1	57		Few old leaves burned.	
*Coelogyne flaccida	5	......	1	62	Chaff scale	No burning	100 per cent killed.
Coelogyne massangeana.	½	......	1	60		do	
Coelogyne speciosa	½	......	1	57		do	
Cymbidium pendulum.	½	......	1	57		do	
Cypripedium callosum.	½	......	1	60	Thrips	do	All stages except eggs killed.
Cypripedium calypso	½	......	1	60	do	do	Do.
Cypripedium spicerianum.	½	......	1	60	do	do	Do.
Cypripedium venustum.	½	......	1	57	do	do	Do.
*Cypripedium sp	5	......	1	62		do	
Dendrobium ainsworthi.	½	......	1	57		do	
Dendrobium aggregatum.	½	......	1	57		do	
*Dendrobium fimbriatum.	5	......	1	62	Lepidosaphes sp.	do	100 per cent killed.
Dendrobium grandiflorum.	½	......	1	57		do	
Dendrobium nobile	½	......	1	60		do	
Dendrobium parishii	½	......	1	57		do	
Epidendrum prismatocarpum.	½	......	1	57		do	
Laelia anceps	½	......	1	57		do	
Laelia acuminata	½	......	1	57		do	
Laelia superbiens	½	......	1	60		do	
Maxillaria graminifolia.	½	......	1	57		do	
Oncidium embratium.	½	......	1	60		do	
Oncidium papiliomajus.	½	......	1	60		do	
Oncidium sphacelatum.	½	......	1	57		do	
Oncidium splendidum	½	......	1	57		do	
Odontoglossum sp	½	......	1	58		do	
Phalaenopsis schilleriana.	½	......	1	60		do	
Pholidota imbricata	½	......	1	57		do	

[1] Orchids in growing condition, practically all having new growth, flower bud, or blossom.
[2] Imported orchids without new growth

TABLE II.—*Results of fumigation with hydrocyanic-acid gas in greenhouses and boxes*—Continued.

[Plants with an * were fumigated in a box.]

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	Greenhouse temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
Orchids—Continued.				°F.			
Schomburgkia tibicinis.	½	......	1	57	....	No burning.....	
Schomburgkia undulata.	5	......	1	62	....	.....do.........	
Sobralia macrantha...	½	......	1	58	....	.....do.........	
Thunia marshalliana.	½	......	1	58	....	.....do.........	
Vanda caerulea......	½	......	1	58	....	.....do.........	
Palms:							
Areca lutescens......	2½	......	1	63	Palm mealybug, tessellated scale.	.....do.........	100 per cent killed.
*Do..........	......	10	1	65	Tessellated scale.	.....do.........	Do.
Cocos plumosa........	2½	......	1	59	Tessellated scale, palm mealybug.	.....do.........	Do.
Kentia belmoreana...	2½	......	1	59	Palm aphid, palm mealybug, thread scale, Florida red scale.	Slight burning of some new growth.	Do.
*Kentia belmoreana..	......	5	½	......	Palm mealybug, palm aphid.	No burning.....	Do.
Kentia fosteriana.....	2½	......	1	59	Palm aphid, Florida red scale, thread scale.	Slight burning of some new growth.	Do.
Latania borbonica....	2½	......	1	63	Thread scale....	No burning.....	Do.
Phoenix roebeleni....	2½	......	1	63	Thread scale, tessellated scale.	.....do.........	Do.
*Phoenix sp.........	......	10	1	73	....	.....do.........	
Rhapis flabilliformis..	2½	......	1	59	Palm mealybug, tessellated scale.	.....do.........	Do.
Pandanus graminifolius.	¾	......	1	68	....	.....do.........	
Pandanus veitchi.......	¾	......	1	68	....	.....do.........	
*Do..............	......	10	1	73	Florida red scale	.....do.........	Do.
Pansy...............	½	......	1	62	Aphids........	.....do.........	Do.
Do...............	5	......	1	52	....	.....do.........	
Pelargonium sp........	¾	......	1	68	Aphids........	.....do.........	75 per cent killed.
Pentstemon sp.........	......	5	¾	52	....	.....do.........	
Do...............	......	7½	1	......	....	Slight burning..	
Petunia..............	½	......	1	60	....	No burning.....	
Poinsettia............	½	......	1	62	....	.....do.........	
Poppy (Shirley)........	½	......	1	60	....	.....do.........	
Poppy (water)..........	2½	......	1	60	....	.....do.........	
Primula (Chinese)......	¾	......	1	56	....	.....do.........	
Do...............	......	5	¾	66	....	.....do.........	
Primula malacoides....	¾	......	1	55	....	.....do.........	
Primula obconica......	¾	......	1	55	....	.....do.........	
Rhododendron.........	......	5	¾	66	....	.....do.........	
Rosemary............	½	......	1	64	....	.....do.........	
Roses (seven commercial varieties).	⅜	......	1	49	....	.....do.........	
Do...............	½	......	1	56	....	New growth burned.	
Sansevieria...........	2½	......	1	63	....	No burning.....	
Scarlet sage..........	¾	......	1	69	....	.....do.........	
Schizanthus sp........	¾	......	1	56	....	.....do.........	
Smilax..............	5	......	1	48	....	New growth burned.	
Snapdragon...........	½	......	1	60	....	New growth and floral spikes burned.	

TABLE II.—*Results of fumigation with hydrocyanic-acid gas in greenhouses and boxes*—Continued.

[Plants with an * were fumigated in a box.]

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	Greenhouse temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°F.			
Spiraea sp	¾		1	60		No burning	
Stephanotis floribunda		5	¾	60		do	
Stevia	½		1	60		do	
Stocks	½		1	62		do	
Swainsona sp	½		1	60		do	
Sweet peas	½		1	60	Aphids	Tips and blossoms burned.	100 per cent killed.
Sweet William	½		1	56		No burning	
Thunbergia erecta	½		1	64		do	
Tulip	¾		1	55		do	
Umbrella plant	2½		1	63	Red spider	do	Do.
Verbena (hardy)	¾		1	60		do	
Verbena (lemon)	½		1	64		New growth burned.	
Vinca major variegata	¾		1	56		No burning	
Do		5	¾	66		do	
Vinca rosea	¾		1	60		do	
Violet	5		1	48	Aphids	do	Do.
Wandering Jew	½		1	64		Severe burning	

In order that there may be no confusion on the part of the reader as to the insects referred to in the tables by their common names, both their common and scientific names are listed herewith:

Greenhouse white fly........*Trialeurodes vaporariorum* (Westw.).
Citrus mealybug........*Pseudococcus citri* (Risso).
Long-tailed mealybug........*Pseudococcus adonidum* (L.).
Palm or avocado mealybug........*Pseudococcus nipae* (Mask.).
Greenhouse Orthezia........*Orthezia insignis* (Dougl.).
Florida red scale........*Chrysomphalus ficus* (Ashm.).
Long scale........*Coccus elongatus* (Sign.).
Soft brown scale........*Coccus hesperidum* (L.).
Palm aphis........*Cerataphis lataniae* (Boisd.).
Hemispherical scale........*Coccus hemispherica* (Targ.).
Florida fern caterpillar........*Eriopus floridensis* (Guen.).
Aspidistra scale........*Hemichionaspis aspidistrae* (Sign.).
Tessellated scale........*Eucalymnatus tessellatus* (Sign.).
Azalea Eriococcus........*Eriococcus azaleae* (Horv.).
Azalea lacewing........*Stephanitis azaleae* (Horv.).
Greenhouse thrips........*Heliothrips haemorrhoidalis* (Bouché).
Thread scale........*Ischnaspis longirostris* (Sign.).
Chaff scale........*Parlatoria proteus* (Curt.).
Spanish red scale........*Chrysomphalus dictyospermi* (Morg.).

FIG. 4.—Greenhouse ready for fumigation.

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HOW INSECTS AFFECT THE COTTON PLANT AND MEANS OF COMBATING THEM

W. DWIGHT PIERCE

Entomologist, Southern Field Crop Insect Investigations

FARMERS' BULLETIN 890

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C. December, 1917

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THE COTTON PLANT is unusually attractive to insects and probably no other cultivated crop has as large a list of insect enemies. Among these are some of the most destructive pests in the history of agriculture.

Many cotton pests come to the cotton from other crops or from weeds around the fields. Weeds should not be allowed to grow.

Rotation of crops is of assistance in controlling cotton pests.

An early crop is necessary.

Poisons seldom are needed, except in poisoned baits in the spring and against red spiders, grasshoppers, and "worms" when they threaten the crop.

Thorough fall plowing, winter cover crops, early spring preparation, and repeated cultivation during the season are important measures of insect control.

The cotton plants should be turned under in the fall.

This bulletin describes the work of many insects and gives suggestions for their control.

A single system of control, effective against most of the insects referred to, is given in summary form on pages 26 and 27.

HOW INSECTS AFFECT THE COTTON PLANT AND MEANS OF COMBATING THEM.

CONTENTS.

HOW COTTON ATTRACTS INSECTS.

NOT ONLY the squares and bolls of cotton, but the leaves and flowers are attacked by insects, and many species attack the stems and roots. In addition to the attraction of the plant to those insects which require it as food, the cotton plant is supplied with a peculiar means of attracting insects. On the underside of cotton leaves, on the midrib, or principal vein, and sometimes also on two other veins, one can find a little elongate depression which usually looks sticky and often holds a drop of liquid. On the outside of the squares at the base of each bract or leaflet are other little cups and between the bract and the bud itself are three more cups. At the bottom of the flower cup still others of these little vessels are found. They are called nectar cups, or nectaries, because they exude a sweet liquid. This liquid is greatly desired by many insects, beneficial and harmful, and is the means of attracting to the cotton plant a great variety of insect life.

As a result of the peculiar attractiveness of cotton for insects many specimens of harmless insects collected at the nectar are sent to entomologists under the impression that they are dangerous pests.

It would be impossible in a publication of this series to mention even briefly all of the cotton pests. The main object is to explain how insects affect the plant and to show how to distinguish the principal ones and how to combat them. The more important species, like the boll weevil and the bollworm, are treated fully in other publications.[1]

[1] See Farmers' Bulletin 848, "The Boll Weevil Problem with Special Reference to Means of Reducing Damage," and Farmers' Bulletin 872, "The Bollworm or Corn Earworm." These may be obtained free from the Division of Publications, U. S. Department of Agriculture.

Insect attack against cotton begins with the seedling and continues until the plant is destroyed when picking is over. It seems best, therefore, to discuss the pests from the standpoint of the season and the manner of attack.

HOW INSECTS MAY BE CONTROLLED BEFORE PLANTING.

The control of many insect pests should begin in the spring before they begin their attack. While they are still in the shelter of woods, buildings, weeds, etc., or dormant in the ground they are most vulnerable.

WEED DESTRUCTION.

Thorough destruction of weeds and cleaning up fence rows and brush will invariably assist in the reduction of insect damage. Such insects as tree crickets and some of the leafhoppers lay their eggs in weed stems. Destruction of the weeds naturally will destroy them. Weed destruction should not stop with the first cutting but should continue through the season. Further emphasis will be placed on this in another section of the bulletin.

WINTER PLOWING.

During the winter the soil is likely to conceal many potential enemies of the crops about to be planted. It is the habit of many species of insects to pass the winter months as larva ("worm" stage) or pupa (resting stage) in cells in the ground, where they are protected from the weather. A winter or very early spring plowing which disturbs them and exposes them to cold and rain is far more effective than any measure taken after they emerge and begin to reproduce. Winter plowing is an aid in the control of the bollworm, cutworms, grasshoppers, May beetles, and many other insects which injure cotton.

PESTS THAT MENACE THE STAND OF SEEDLING COTTON.

Many factors in cotton production have combined to make it necessary that the farmer push the growth of his cotton plantings as rapidly as possible. This is especially important in order that the greater part of the crop may be made before insect injury can reach its maximum. Of course this means that the planter must plant as early as it can be done with reasonable expectation of escaping a killing frost. Every farmer who has lived a number of years in a locality knows the usual time that the last frosts occur on his place and also knows which parts of a plantation are to be planted early and which later. He understands that some of his land is cold and slow to develop plant growth and that some of it is warmer and permits a more rapid growth. In case of doubt the planter should ask advice from his State experiment station or the county demonstration agent.

In view of the necessity for an early crop, it is obvious that anything which retards the growth of the seedling cotton, or injures the stand so as to necessitate a replanting, is a serious drawback.

CUTWORMS.

The stand of cotton frequently is injured very seriously by cutworms (figs. 1, 2), of which there are numerous species. These "worms" are from one-half to an inch in length and of a dirty color.

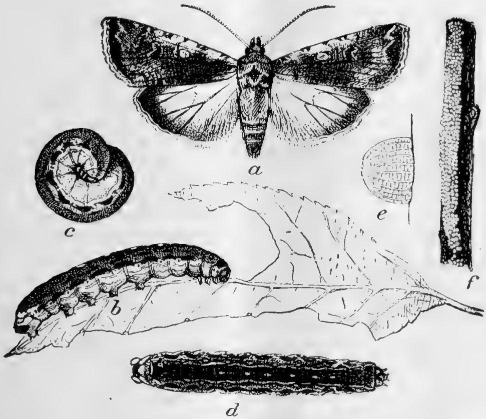

Fig. 1.—Varigated cutworm (*Peridroma margaritosa*): *a*, Moth; *b*, normal form of caterpiller, side view; *c*, same in curved position; *d*, dark form, view of back; *e*, greatly enlarged egg, seen from side; *f*, egg mass on twig. (Howard.)

They hide in the ground in the daytime and come out at night to do their work, which consists in cutting the stem in two or feeding on the leaves. The same kind of work is sometimes done early in the season by the nearly related southern grass worm,[1] but this species rarely attacks the plant until later.

The use of a poisoned bait is advisable if cutworms are numerous. This may be prepared as follows: Mix 50 pounds of wheat bran and 2 pounds of Paris green. 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 infested field in small lumps. In case bran can not be obtained readily, middlings or alfalfa meal may be substituted. In fields known to be infested the distribution of this bait

[1] *Laphygma frugiperda* S. and A.

should be begun as soon as the cotton starts to appear above ground, so that the cutworms may be eliminated as quickly as possible and the skips replanted promptly. 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 usually

FIG. 2.—A cutworm, *Agrotis ypsilon: a,* Larva; *b,* head of same; *c,* adult moth. Natural size. (Riley and Howard.)

will be more effective if applied during the late afternoon or early evening. Frequently cutworms migrate to cultivated fields from adjoining grassland, and in such cases the crops can be protected by placing the poisoned bait around the edge of the field or along the side nearest the source of infestation.[1]

MAY BEETLES.[2]

In western Texas and Oklahoma several species of May beetles (figs. 3, 4) cause considerable injury to seedling cotton plants. These beetles pass the winter in the grub stage in the ground, maturing in the spring. The wingless species are especially likely to injure the cotton if it is planted on newly broken fields or fields which were very grassy in the preceding year. These forms, being unable to fly, must attack the nearest vegetation. Some of the winged species also are reported as injurious to cotton. As has already been pointed out, winter plowing is of assistance in checking these beetles. The poisoned baits recommended for cutworms are of value against them.

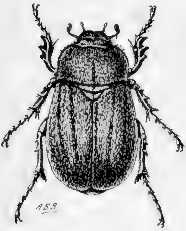

FIG. 3.—May beetle, *Phyllophaga lanceolata.* Enlarged. (Sanderson.)

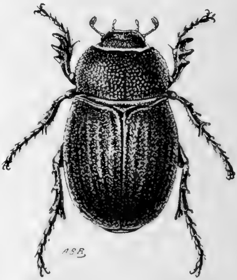

FIG. 4.—May beetle, *Phyllophaga cribrosa.* Enlarged. (Sanderson.)

[1] Extracted from Farmers' Bulletin 739. This bait is of value in the control of other pests and will be mentioned several times in this bulletin.

[2] (*Lachnosterna*) *Phyllophaga* spp.

OTHER PESTS THAT INJURE SEEDLINGS.

Many other pests from time to time seriously affect stands of seedling cotton in various parts of the country. Occasionally an early grasshopper outbreak occurs. In parts of Alabama and Mississippi cotton stands frequently are destroyed in a night by crayfish colonies. These creatures are not insects, but belong to the class of animals called Crustacea, which includes the crabs and lobsters. As they occur only where there is a considerable amount of water underground, their control is largely a matter of drainage. They live in colonies in a large chamber at the water level and reach the surface of the ground by long "chimneys." The placing of about an ounce of carbon disulphid in each "chimney," its opening thereupon being closed, will kill the inmate. Crustaceans of another group which injure cotton seedlings are the sowbugs and pill bugs.[1] They can be controlled readily by poisoned baits.

INJURIES WHICH ABORT THE GROWTH.

COTTON APHIS.[2]

One of the earliest insects to be found on the plant is the cotton aphis or "cotton louse" (fig. 5), which also attacks many other plants. The green "lice" are not conspicuous, but the rate of multiplication is so rapid that they can become a very serious pest. They suck the juices of the plant, sometimes causing death and often a curling or dwarfing of the leaf and malformation of the plant. They are seldom of enough importance to necessitate remedial measures, but when they attack small plots of cotton planted for purposes of selection, etc., it is advisable to spray with 40 per cent nicotine sulphate used at the rate of three-fourths of a pound to 100 gallons of water. Preventive measures, such as fall and winter plowing, to destroy them on their weed host plants, are much more effective than direct remedies.

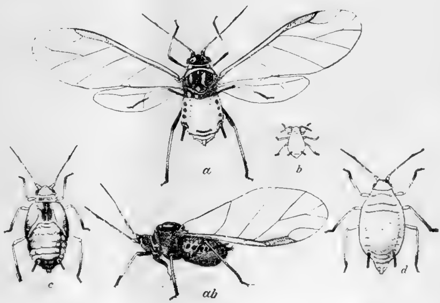

FIG. 5.—Cotton aphis: *a*, Winged female; *ab*, dark female, side view; *b*, young nymph, or larva; *c*, last stage of nymph; *d*, wingless female. All much enlarged. (Chittenden.)

[1] *Armadillidium vulgare* Latr., *Porcellio laevis* Latr., etc.

[2] *Aphis gossypii* Glov.

SOUTHERN GRASSWORM.[1]

The southern grassworm, or fall army worm (fig. 6), is not native to the United States, although occasionally it winters over in the extreme southern portions of the country. It feeds on many plants, grasses, and cultivated crops and is often a serious pest. Winter control is of no avail, as the attack follows the flight of the moths into new territory. The larvæ work very rapidly and cause considerable injury to the plants by gnawing the stem partly in two, eating the growing tips, and causing other injuries which result in a distorted growth and dwarfing of the plant.

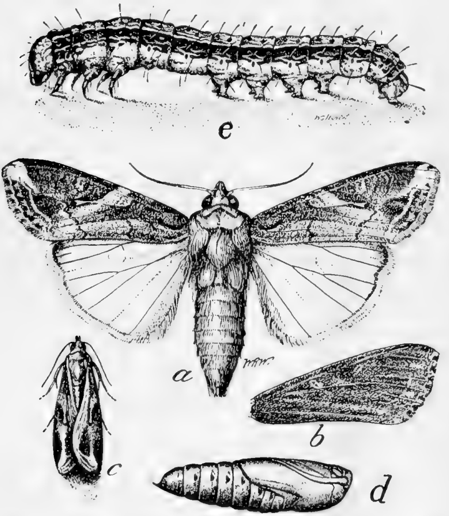

FIG. 6.—Southern grass worm, or fall army worm: *a*, Adult male moth; *b*, right front wing of female moth; *c*, moth in resting position; *d*, pupa; *e*, full-grown larva. *a*, *b*, *d*, *e*, about twice natural size; *c*, slightly enlarged. (Walton and Luginbill.)

When numerous on cotton, powdered arsenate of lead should be applied at the rate of about 5 pounds per acre. The usual method of utilizing cloth sacks on poles carried through the field on the back of a horse or mule is perfectly adapted to this crop. The following description of the construction and use of the outfit needed for this purpose is quoted from Farmers' Bulletin 872, "The Bollworm or Corn Earworm:"

A 4-inch board about 18 inches longer than the distance between the rows is used for the pole. To form the bags at either end, four blocks of the same material, each about 4 inches long, are nailed endwise to the underside of the pole. One of these is placed at each end and the other two about 16 inches from these to form the ends for the rectangular-shaped bags. An inch or one and a half inch hole is then bored through the pole about 8 inches from either end for pouring the poison into the bags. These holes are closed with corks when the outfit is in use. The sides of a rectangular piece of cloth are then tacked along each edge of the pole, and the ends to the side, and bottom of the blocks. If unadulterated Paris green is to be used, 8-ounce duck may be used for the bag, but lighter material is necessary for powdered arsenate of lead or Paris green mixed with flour. The poison sifts out over the plants as the pole is jarred by striking it with a

[1] *Laphygma frugiperda* S. and A.

stick as it is carried across the back of a mule ridden between the cotton rows. Two rows are thus treated at once and from 15 to 20 acres can be covered by one man during the early morning and evening hours which are suitable for the work. It is best to apply the poison when the plants are moist with dew so that it will adhere to the foliage. It is also necessary to avoid windy periods.

If the worms are in grass plots or cultivated fields adjoining cotton, the poisoned bait described for cutworms will be effective in keeping them from the cotton. In some cases where the ground is hard, with little vegetation, the use of heavy rollers or brush will be of advantage in crushing the worms. Deep furrows around the field will catch many worms moving into a field and in these they may be crushed.

When they are full grown they enter the soil and change to pupæ. A shallow cultivation by disking or with a spring-tooth harrow at this time is very effective, as it will kill many pupæ and expose others to the heat of the sun.

INJURIES TO THE GROWING TIP.

The growing tip of cotton frequently is injured by insects which make their principal attack on other parts. The boll weevils in the spring frequently injure the terminal bud when they emerge from hibernation before the squares form. Grassworms, cutworms, and grasshoppers do similar injury. Frequently small "worms" which make a web around the leaf or bud are to be found. These belong to

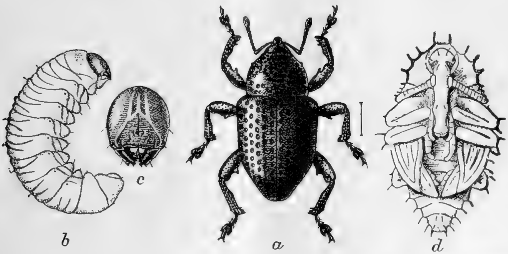

Fig. 7.—Cowpea-pod weevil: *a*, Adult weevil; *b*, larva, side view; *c*, head of same, front view; *d*, pupa, viewed from below. Much enlarged. (Chittenden.)

several different genera[1] of moths and are not often of grave importance. As they are usually insects which normally attack some weed, another argument for weed control and fall plowing is afforded.

The cowpea-pod weevil[2] (fig. 7) frequently attacks young cotton and causes injury by puncturing the terminal bud. These attacks usually occur when cotton follows cowpeas.

[1] Platynota, Loxostege, etc.

[2] *Chalcodermus aeneus* Boh.

LEAF INJURIES AND DEFOLIATION.

Cotton leaves are attacked by many insects, some of which are usually considered of little importance, although in small areas they frequently do serious injury. Dusting with arsenate of lead is probably the best general remedy for cotton defoliators, such as beetles, "worms," and grasshoppers. This may be done by the pole-and-bag method or by the use of a dust gun with a rotary fan.

COTTON LEAFWORM.[1]

The best known defoliator of cotton is the cotton leafworm (fig. 8), sometimes called the cotton army worm. It is not present in the country every year. It is a native of tropical regions, but from time to time it flies to this country and often by the end of the season has stripped the cotton fields of foliage. The moths are tawny, with a wing expanse of slightly more than an inch. They lay small green eggs singly on the leaves of cotton. The larvæ are elongate, somewhat variable in coloring, some being yellowish green without prominent stripes, while others have a black stripe down the back with a fine central yellow stripe. Each segment has four black dots above. The larva when full grown webs one or two leaves together to form a cocoon and pupates therein, hanging the pupa by a thread to the stem. As the worms do not attack other plants and do not enter the ground, cultivation and weed control are of no avail against this species. When the attack is late in the season the defoliation is often beneficial, as it hastens the ripening of the fruit and cuts off the food supply of the boll weevil. But often the worms appear so early as to be capable of inflicting serious damage, especially to late crops. In such cases it is advisable to dust with arsenate of lead at the rate of about 4 pounds to the acre, more or less, depending on the size of the cotton. It is best to apply the poison when the leaves are moist with dew and when the winds are low. The planter should not wait until the defoliation is heavy.

GRASSHOPPERS.

Frequently the cotton fields of Texas and sometimes of the other cotton States are seriously injured by grasshoppers, among which the differential grasshopper[2] (figs. 9, 10) and the Southwestern lubber grasshopper[3] (fig. 11) are the most injurious.

These insects lay their eggs in masses in the ground and therefore are subject to control by cultivation where that is possible. The grasshoppers usually advance on cotton fields from near-by waste places. Where young grasshoppers appear in great numbers they may be controlled by spraying with kerosene or crude oil, trapped by the poisoned bait mentioned for cutworms, or crushed by drags or

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[1] *Alabama argillacea* Hübn. [2] *Melanoplus differentialis* Thos. [3] *Brachystola magna* Gir.

FIG. 8.—Cotton leafworm: Stages and work.

rollers. When the lubber grasshoppers appear, control measures must be taken immediately, because these insects can destroy a plant very quickly.

COTTON RED SPIDER.[1]

One of the most destructive enemies of cotton is the red spider (figs. 12–15), which is not an insect, but a mite. These mites can hardly be seen on the cotton leaf, except by a trained eye or with the aid of a magnifier, unless very numerous, when their minute moving red bodies make them distinguishable. They multiply so rapidly that they may spread from a single infested weed over an entire cotton field during the season. They suck the juices and cause the leaf to turn red and finally kill the plant. They usually work on the underside of the leaf.

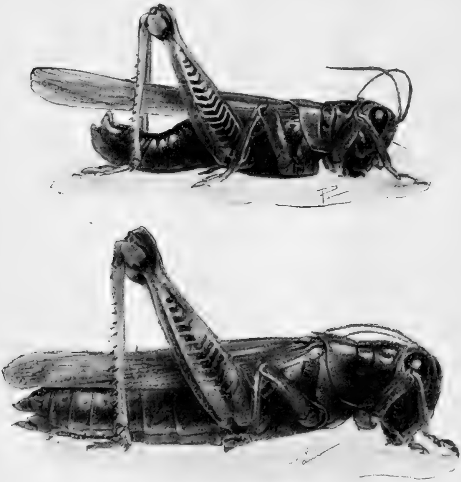

FIG. 9.—Differential grasshopper: Above, adult male; below, adult female. Twice natural size. (Walton.)

As the red spider is dependent on other plants to carry it through the winter, it is apparent that weed control is a very important element in reducing damage by this pest. Special bulletins are available for those desiring complete information.[2]

The destruction of weeds, especially the pokeweed, and of cultivated plants such as the violet, from which the mites make their way to the cotton, and the destruction by plowing up and burning of early infested cotton plants are effective measures, which should be used as primary means of control.

FIG. 10.—Egg mass of differential grasshopper. Enlarged. (Sanderson.)

When a cotton field is threatened by the red spider it is often advisable to spray. The following sprays are effective: (1) Potassium sulphid (1 ounce to 2 gallons of water); (2) lime-sulphur solution

[1] *Tetranychus telarius* L.

[2] Department Bulletin 416, "The Red Spider on Cotton," and Farmers' Bulletin 831, "The Red Spider on Cotton and How to Control it."

(homemade or commercial); (3) kerosene emulsion [1]; (4) flour-paste solution (1 gallon stock paste to 12 gallons water).

LEAF-CUTTING ANT. [2]

The so-called leaf-cutting or parasol ant is well known in southwestern Texas, where it is often destructive to cultivated crops, in-

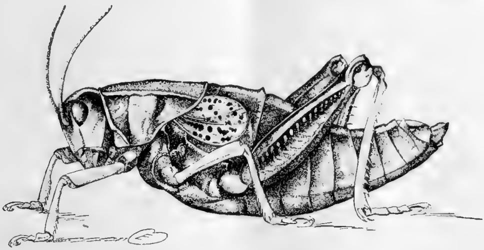

FIG. 11.—Southwestern lubber grasshopper; Adult female, natural size. (Walton.)

cluding cotton. The ants cut the leaves from a plant and carry them to the nest The leaves are finely divided and made into small pellets, by means of the mandibles and legs. The pellets are placed upon the so-called fungus garden, where they furnish a growing medium for the fungus on which the colony feeds.

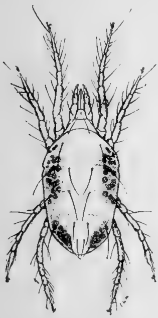

FIG. 12.—The female red spider. Highly magnified. (McGregor and McDonough.)

FIG. 13.—Cotton plant in well advanced stage of infestation by the red spider. Nearly all leaves, squares, and bolls have been shed. (McGregor.)

The best method of control is by means of potassium or sodium cyanid, a deadly poison. The cyanid is used at the rate of 1 ounce to 1 quart of water. After careful mixing the liquid is poured into each opening of the nest, a quart to an opening. Two applications may be necessary to exterminate the colony. *Care must be taken not to breathe*

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[1] Kerosene emulsion is made by combining 1 gallon of kerosene and one-fourth pound of laundry soap, or 1 pound of whale-oil (fish-oil) or other soap, or 1 pint of soft soap, with half a gallon of water. The laundry soap, if dry, is shaved and dissolved in boiling water and then poured (away from the fire) while still boiling hot into the kerosene. The mixture is then churned rapidly 8 or 10 minutes, the liquid being pumped back upon itself by means of a sprayer with a nozzle throwing a strong, solid stream. At the end of this time the mixture becomes a thick cream—the stock emulsion. In the preparation of the emulsion a sprayer is necessary. For most species of sucking insects 1 part of the stock emulsion should be mixed with 15 parts of water.

[2] *Atta texana* Buckley.

the deadly fumes of this poison. Gloves should be used in handling this poison to prevent any of it from coming in contact with abrasions of the skin. The action of the poison on the blood is more deadly than the fumes which might be breathed in the handling, when done out of doors. All refuse should be buried immediately, and the hands washed carefully.

FIG. 14.—A severe example of red-spider work in a cotton field. Nearly all plants in the foreground are in the condition shown in figure 13. The source of infestation was certain pokeweed stalks growing in the weed border seen in the upper right-hand corner of the picture. (McGregor.)

FIG. 15.—Ideal spraying outfit for treatment of considrable red-spider infestation. (McGregor.)

SALT-MARSH CATERPILLAR.[1]

The salt-marsh caterpillar (fig. 16) is one of the species of "woolly-bears," several of which may at times seriously injure cotton. This species is almost always to be found in the fields. The eggs are laid in masses. The larvæ are covered with long hairs and are somewhat variable in color. They feed on many kinds of foliage and usually come to the cotton fields from some adjoining weedy area. The

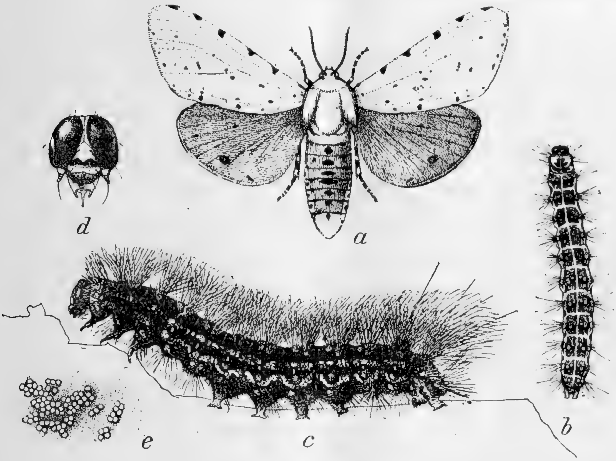

FIG. 16.—Salt-marsh caterpillar: *a*, Female moth; *b*, half-grown larva, or caterpillar; *c*, full-grown larva, side view; *d*, head of larva, front view; *e*, egg mass. All slightly enlarged, except *d*, which is more enlarged. (Chittenden.)

larvæ when full grown spin a silken cocoon surrounded by rubbish, on the ground or among the leaves of the plant.

Control of the weeds around the field is naturally the best way of preventing damage by this species and its allies.

OTHER LEAF EATERS.

Many other kinds of caterpillars occasionally injure cotton, such as that of the large tiger moth,[2] the beet army worm,[3] the fall web-worm,[4] and that of the io moth.[5] The larvæ of the io moth are green and covered with poisonous spines. They are very pretty and also well known, to all who have ever touched them, as "stinging caterpillars." They cause a very painful rash when touched. If abundant enough to warrant it, all of these insects can be controlled by dusting

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[1] *Estigmene acraea* Dru.
[2] *Apantesis arge* Dru.
[3] *Caradrina exigua* Hübn.
[4] *Hyphantria cunea* Dru.
[5] *Hyperchiria io* Fab.

the plants with arsenate of lead, but they will not be serious if proper attention is given to surrounding vegetation on which they feed normally.

HOW INSECTS REDUCE THE YIELD.

Naturally the most serious injury to the cotton crop is that which affects the squares, flowers, and bolls, and among the insects causing this injury are some of the most serious known insect pests.

COTTON-BOLL WEEVIL.[1]

The worst cotton pest in this country, and probably the most destructive cotton insect in the world, is the Mexican cotton-boll weevil (figs. 17, 18), which annually takes a toll of tens of millions of dollars from the cotton industry. As this insect is of such great importance, many bulletins have been written about it, and the most recent of these may be obtained on application to the Division of Publications, United States Department of Agriculture, Washington, D. C. The boll weevil lays its eggs in the squares and bolls. Generally the squares which have been attacked will fall to the ground in a few days. They always flare and often hang and dry on the plant. The eggs hatch into small white grubs, or larvæ, with yellowish-brown heads. These feed in the square or boll and grow until they are half an inch long. They usually are curved and are legless. When full grown the grub forms a hard cell and turns into a pupa, which matures in about three days into the adult weevil.

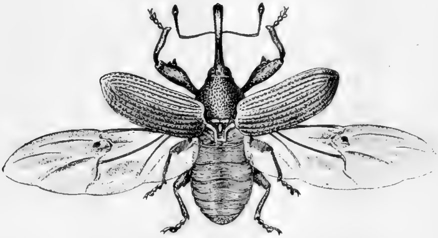

FIG. 17.—Adult female boll weevil with wings spread. Much enlarged. (Hunter and Pierce.)

The weevil is easily detected in a field. If a square is found with its bracts flared and showing a little wartlike puncture, it can be put into a tumbler and covered with cheesecloth. After 2 or 3 days the white larva can be easily found, and in about 10 or 12 days the full-grown weevil will come out.

The control of the weevil is brought about by early planting, selection of the best local varieties, intensive cultivation, early picking of the crop, and destruction of the cotton plants, or at least destruction of the green growth, before frost. All of these methods will also help in controlling the other cotton pests.

[1] *Anthonomus grandis* Boh.

FIG. 18.—Cotton plant attacked by boll weevil: *a*, Hanging dry square infested by weevil; *b*, flared square, with weevil punctures; *c*, cotton boll, sectioned, showing attacking weevil and weevil larva in its cell. (Hunter and Pierce.)

BOLLWORM.[1]

The well-known bollworm (figs. 19, 20) is called the corn earworm when it attacks the ears of corn. It is likewise a pest of tomatoes, tobacco, beans, and alfalfa. The eggs are laid singly. The larvæ bore into the squares and bolls and eat out the interior, usually leaving by another hole and going to another square or boll.

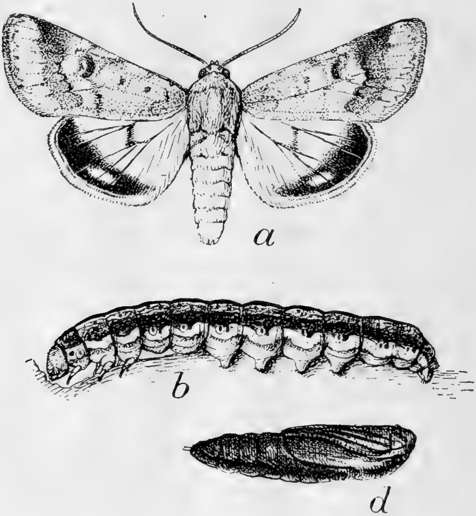

FIG. 19.—Bollworm: *a*, Moth, or adult; *b*, larva, or worm; *d*, pupa. About natural size. (Howard.)

Thus a single worm during its development may injure all the forms on several branches. When full grown, it enters the ground for pupation, emerging in about two weeks as a moth. The bollworms pass the winter as pupæ in the soil.

Thorough plowing of the land during the fall and winter and frequent cultivation of the growing crop will destroy many bollworm pupæ and expose others to the action of rain and frost, sunshine, and insect enemies, and to insect-eating birds and rodents. In combatting the bollworm as well as the weevil an early crop is necessary. If its attack is very serious, poisoning with powdered arsenate of lead by the pole-and-bag method, described under "Southern grass worm," p. 8, is to be recommended.

[1] (*Heliothis*) *Chloridea obsoleta* Hübn.

COTTON SQUARE-BORER.[1]

Frequently the squares are bored by small, oval, flattened, pea-green, velvety-haired larvæ, known as square-borers (fig. 21). Each larva can destroy many squares. The larvæ transform into small pupæ, and when mature these become the dainty little blue swallow-

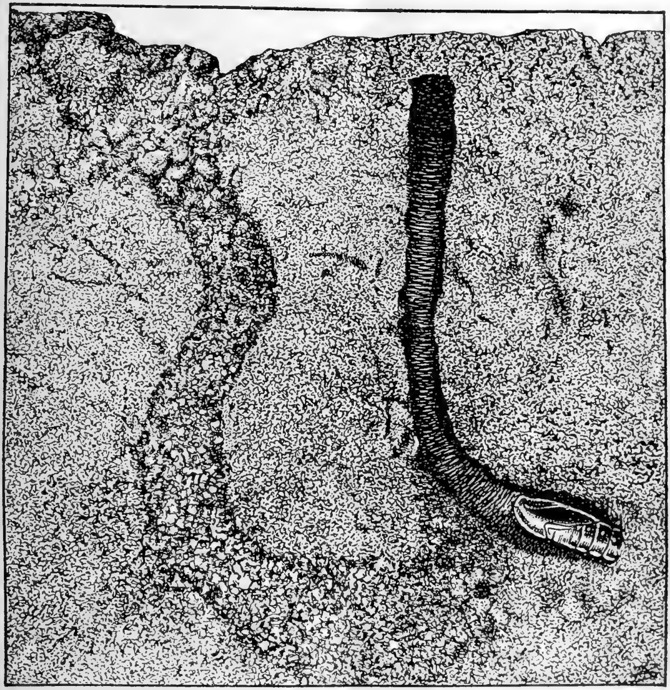

FIG. 20.—Vertical section through the soil, showing pupa of bollworm in its burrow. (Bishopp and Jones.)

tailed butterflies so often seen in the cotton fields. It is seldom necessary to take active measures against them, but when advisable powdered arsenate of lead is recommended.

COTTON-BOLL CUTWORM.[2]

The cotton-boll cutworm (figs. 22, 23) looks like an ordinary cutworm but it feeds by day on the foliage and bores into squares and bolls. The larvæ are olive or greenish brown and easily recognized by the

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[1] *Uranotes melinus* Hübn. [2] *Prodenia ornithogalli* Guén.

two rows of triangular velvety-black spots extending down the back. Four or five broods a year occur in Texas. By picking them off of young cotton when chopping in the spring they may be largely controlled. As they pupate in the soil, frequent cultivations destroy the pupæ.

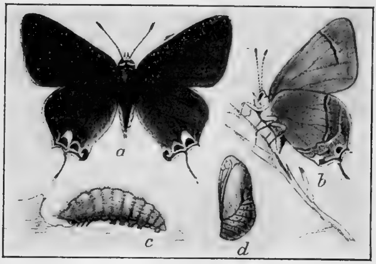

FIG. 21.—Cotton square-borer: *a*, Adult butterfly, top view; *b*, same from side, with wings closed; *c*, larva, or borer, from side; *d*, pupa; *e*, egg. *a-d*, Somewhat enlarged; *e*, greatly enlarged. (Howard.)

COTTON STAINER.[1]

The cotton stainer (fig. 24) is important only in the Southeast, especially in Florida. It is a sucking bug with a long beak. The body is red, with dark-brown or black wings. It feeds on the juices of many plants. The young are similar to the adult except that the wings are not developed. Much injury is done to cotton by the staining of the fiber. In sections where this bug is abundant, measures should be taken to hold down the growth of weeds, upon which the stainer breeds in great numbers. Principal among these weeds are Spanish cocklebur[2] and nightshade.[3] They may be trapped by placing small bunches of cotton seed in different parts of the field.

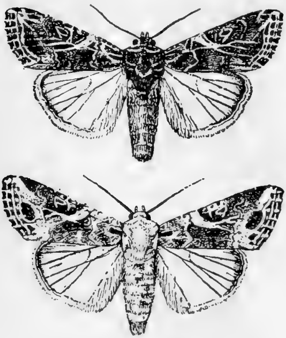

FIG. 22.—Cotton-boll cutworm: Above, dark form of moth, male; below, pale form of moth, female. Somewhat enlarged. (Chittenden.)

FIG. 23.—Cotton-boll cutworm: *a*, Light form of larva; *b*, dark form of larva. Somewhat enlarged. (Chittenden.)

As soon as the young bugs make their appearance in the spring, the colonies should be sprayed with kerosene emulsion, or jarred into buckets of water having a film of kerosene.

[1] *Dysdercus suturellus* H. Schf. [2] *Urena lobata.* [3] *Solanum nigrum.*

COTTON BUGS.

Many different species of sucking bugs[1] attack the cotton squares and bolls and do serious injury. Many of them are known as

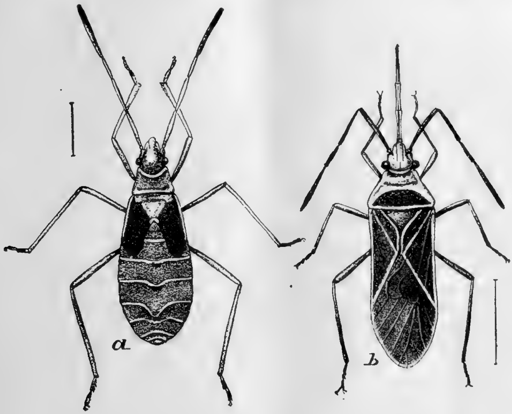

FIG. 24.—Cotton stainer: *a*, Fourth-stage nymph, or pupa: *b*, adult. Enlarged. (Insect Life.)

"pumpkin bugs" and "stinkbugs," but most of them are simply called plant-bugs.

Usually they breed on many plants besides cotton and are kept under control best by preventing excessive weed growth around cotton fields. It has been proved that some of these bugs carry plant diseases of cotton, and hence they are to be regarded as serious pests. Several species are illustrated (see figs. 25–29).

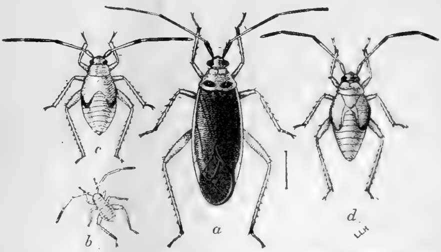

FIG. 25.—Cotton leaf-bug, *Adelphocoris rapidus*: *a*, Mature bug; *b*, young nymph; *c*, fourth stage of nymph; *d*, fifth stage of nymph. Much enlarged. (Sanderson.)

FLOWER BEETLES.

Frequently beetles are found in the blooms of cotton, and occasionally they are numerous enough to do much damage. The blister beetles[2] (see fig. 30) and soldier beetles[3]

[1] *Adelphocoris rapidus* Say, *Leptoglossus phyllopus* L., *Largus succinctus* L., *Nezara hilaris* Say, *Jadera haematoloma* H.-Schf., etc.

[2] *Epicauta vittata* Fab., *E. lemniscata* Fab., *E. cinerea* Forst., *E. ferruginea* Say, etc.

[3] *Chauliognathus* spp.

feed on the petals and eat the pistil and stamens. In case of injury to the pistil the boll frequently fails to mature. These insects in their immature stages prey on other insects and are beneficial.

LEAF BEETLES.

A number of small leaf beetles—some brown, some blue, some green, or striped with yellow—occur on cotton squares and feed on the bracts or sometimes eat the leaves of cotton. They are native to weeds around the fields, and are seldom important.

FIG. 26.—Cotton boll showing punctures of a cotton leaf-bug, *Adelphocoris rapidus*. (Sanderson.)

INJURIES TO THE STALK AND ROOTS.

COTTON WIREWORMS.

In South Carolina much injury is done to the roots of cotton by wireworms[1] (see fig. 31). The adults of these worms are the well known click-beetles so abundant at the flowers and squares of cotton. They are controlled best by using a crop rotation in which cotton follows oats and corn follows cotton. The oats stubble should remain on the land until September 15. After this time it is well to prepare the land and plant a winter cover crop. The cover crop should be supplemented with stable manure, swamp muck, or lime, as it is necessary to build up soil infested by wireworms.

CORN ROOT-APHIS ON COTTON.[2]

Especially in South Carolina the cotton is attacked at the roots by the root-aphis of corn. This insect is similar in appearance to the cotton aphis but confines its attacks to the taproot of cotton. The best control is a three-year system of rotation in which cotton does not follow either corn or cotton. Small grain or cowpeas should precede cotton on badly infested lands. The three-year rotation of oats and cowpeas, cotton, and corn has proved successful. It is of great value to have a winter cover crop on infested lands at all times, as it prevents the winter food plants of the cotton root-aphis from growing upon the land.

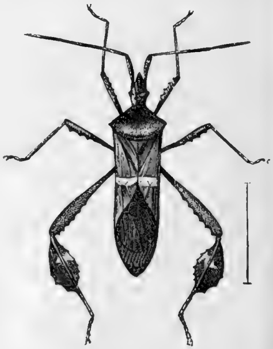

FIG. 27.—Leaf-footed plant-bug (*Leptoglossus phyllopus*) twice natural size. (Hubbard.)

[1] *Monocrepidius vespertinus* Fabricius, *Horistonotus uhleri* Horn, and related species. For an account of these and other species see Farmers' Bulletins 725 and 733.

[2] *Aphis maidiradicis* Forbes.

MOTH STALK-BORER.[1]

Occasionally cotton stalks are bored by the caterpillar of the stalk-borer (fig 32). Ordinarily it attacks various weeds, including "bloodweed."[2] Weed destruction, therefore, is the obvious control measure.

FIG. 28.—A plant-bug, *Leptoglossus oppositus*. Twice natural size. (Chittenden.)

COTTON STALK-BORER BEETLE.[3]

The cotton stalk-borer beetle sometimes is found in Texas boring in cotton stalks, but it is supposed to attack only plants damaged by some other agency.

SNOWY TREE CRICKET.[4]

In the fall of the year cotton stalks frequently are found with the stems roughened by the egg punctures of the snowy and other tree crickets. These tree crickets also oviposit in weeds. They pass the winter in the egg stage in the old stalks and in the spring the young crickets hatch. They feed on vegetation of all kinds. Fall destruction of cotton stalks and weeds is a practical control measure.

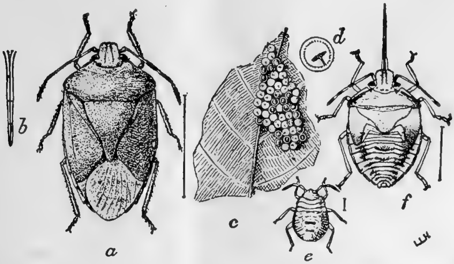

FIG. 29.—The green soldier bug (*Nezara hilaris*): *a*, Mature bug; *b*, beak of same; *c*, egg mass; *d*, single egg; *e*, young nymph; *f*, last stage of nymph. All enlarged; *b*, *d*, more enlarged. (Sanderson.)

SHARPSHOOTERS.[5]

The leafhoppers seen so frequently on the cotton stalks (see figs. 33–36) in the late summer and fall, dodging out of sight around the stem, are commonly called "sharpshooters" with the doubtful

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[1] *Papaipema nitela* Guén.

[2] *Ambrosia trifida* and other species of Ambrosia.

[3] *Ataxia crypta* Say.

[4] *Oecanthus niveus* DeG.

[5] *Homalodisca triquetra* Fab., *Oncometopia undata* Fab., *Oncometopia lateralis* Fab., and *Aulacizes irrorata* Fab.

assumption that they puncture the squares and bolls. They do puncture the stalks and lay their eggs in the leaves just under the surface, forming a blisterlike mark.

INSECTS IN DECAYED AND DRY BOLLS.

Cotton bolls which have become affected by anthracnose and other diseases furnish an attraction to many bugs and beetles, which no doubt often are instrumental in spreading the infection. Very few of these insects found feeding in the rotten spots have any primary importance to the cotton plant. Dry bolls which have matted fiber are often filled with small beetles, little white "worms," and larger pink "worms." These are all feeders on decayed matter. (The pink "worms" are not to be confused with the pink bollworm [1] of cotton which ultimately may become a pest in this country, the larvæ of which will be found in the winter in bolls with healthy fiber, in seeds, or in cells formed by uniting two seeds.) Boll-weevil larvæ, pupæ, and adults frequently may be found in cells in old bolls, which in addition may serve as shelter for other pests. As some of the insects which are merely scavengers in cotton bolls are recorded as injurious on other plants, it is important that all cotton plants be disposed of as soon after the cotton is picked as is practicable.

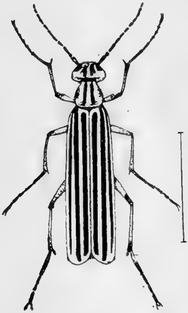

FIG. 30.—A blister beetle, *Epicauta lemniscata*. Enlarged. (Chittenden.)

THE DOUBLE RÔLE OF ANTS.

Of course every cotton field has its ant colonies. When the ants are large species, such as the leaf-cutting ant [2] or the Texas agricultural ant,[3] the colonies should be destroyed as described under the paragraph on the former (p. 13). The smaller ants which swarm over the cotton plants are very helpful in ridding the plant of many enemies,

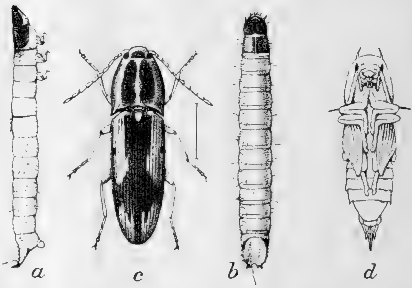

FIG. 31.—A cotton wireworm, *Monocrepidius vespertinus*: *a*, Larva, or wireworm, side view; *b*, same, top view; *c*, adult, or beetle; *d*, pupa. Much enlarged. (Chittenden.)

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[1] *Pectinophora gossypiella* Saunders.
[2] *Atta texana* Buckley.
[3] *Pogonomyrmex barbatus molefaciens* Buckley.

for they attack in numbers insects much larger than themselves. Several species of ants[1] are very efficient enemies of the boll weevil.

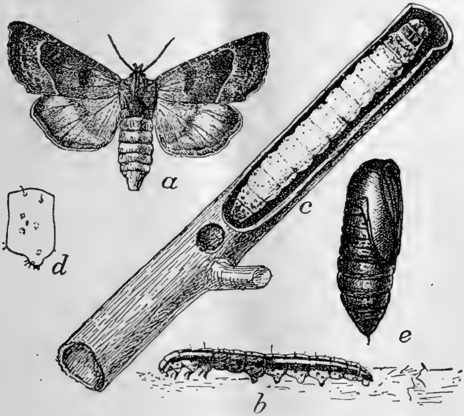

FIG. 32.—Moth stalk-borer: *a*, Female moth; *b*, half-grown larva, or borer; *c*, full-grown larva in injured stalk; *d*, side view of segment of abdomen of same; *e*, pupa. All somewhat enlarged. (Chittenden.)

They eat their way into fallen infested squares and devour the weevil larvæ, pupæ, and adults. In this way they often add 10 to 20 per cent to the natural control of the weevil. But these same ants are fond of sweets and they foster the honeydew-secreting aphids, white flies, and scales, which are found on cotton, transplanting them to new colonies. They are diligent in protecting the aphids, or "lice," from voracious enemies and in this way become enemies of the cotton planter. On the whole, however, it is believed that the smaller ants do at least as much good as harm and should be let alone.

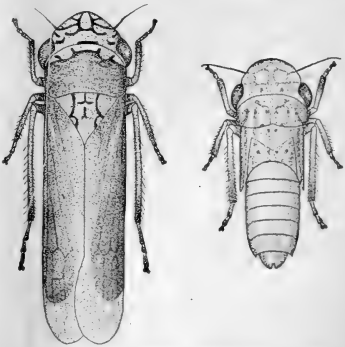

FIG. 33.—A "sharpshooter," *Oncometopia undata:* Adult at left, nymph, or young, at right. Greatly enlarged. (Sanderson.)

THE PARASITES.

Practically all of the pests mentioned on other pages are held more or less in control by other insects which prey on them or live at their

[1] Especially species of Solenopsis, Pheidole, Monomorium, and Iridomyrmex.

expense. The little parasites are so inconspicuous that they seldom are seen, but often their work is very effective. All the measures which are recommended for the control of the various pests, except the use of poisons, will serve to favor parasite attack, which will go on without other effort by the planter.

INSECT VISITORS OF COTTON.

Many of the wasps and bees that visit cotton are there only for nectar or pollen and incidentally they serve to fertilize the plants. It is thus that most of our plants are fertilized. The nectar attracts multitudes of insects which have nothing to do with cotton otherwise. When weeds are allowed to grow and nourish pests and are suddenly cut or destroyed, one may expect a large increase of insects on cotton, many of which will be injurious. *The weeds must not be allowed to grow.*

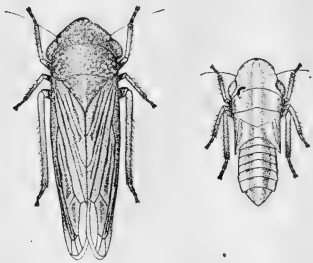

FIG. 34.—A "sharpshooter," *Oncometopia lateralis:* Adult at left; nymph, or young, at right. Greatly enlarged. (Sanderson.)

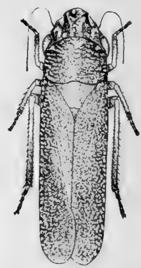

FIG. 35.—A "sharpshooter," *Aulacizes irrorata:* Adult. Greatly enlarged. (Sanderson.)

SUMMARY OF CONTROL MEASURES.

In summary of the preceding paragraphs a single system may be devised for cotton-insect control.

BEST MEASURES FOR THE EARLY SPRING.

1. Keep down weed growth around the farm.
2. Plow in the winter to break up the winter cells in the ground.
3. When necessary set out poisoned baits to trap cutworms, grasshoppers, May beetles, etc.
4. Plant as early as it can be done safely and yet avoid killing frosts. Plant the variety which is found to be the best producer in your own locality, and which has the qualities of rapid and prolific fruiting.
5. Space the rows in accordance with local experience
6. Cultivate frequently, but not deeply.

BEST MEASURES TO FOLLOW DURING THE SUMMER.

1. Continue cultivation until the crop is made, or as long as possible.
2. Watch for the first appearance of worms.
3. Dust the cotton with powdered arsenate of lead as soon as grasshoppers or "worms" begin to attack, unless "worm" attack starts late and would hasten ripening.
4. Keep down the weeds.

WHAT TO DO IN THE FALL.

1. Pick the cotton out as soon as possible.
2. Destroy the plants by plowing under or grazing as long before frost as possible.
3. Where practicable plow the fields and plant a cover crop.
4. Where feasible follow a three-year rotation with cotton following some crop other than corn.

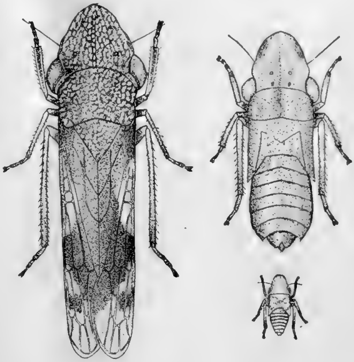

FIG. 36.—A "sharpshooter," *Homalodisca triquetra:* Adult at left; last-stage nymph, or young, at right, above; young nymph at right below. Greatly enlarged. (Sanderson.)

PRACTICAL MEASURES FOR THE WINTER.

1. Clean up all turn rows and fence rows.
2. Cut and burn all weeds.
3. Plow under all stubble fields that are not to be used otherwise.
4. Grub up old stumps.

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE RELATING TO INSECTS INJURIOUS TO COTTON OTHER THAN THE BOLL WEEVIL.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Fall Army Worm, or "Grass Worm," and its Control. (Farmers' Bulletin 752.)

Red Spider on Cotton and How to Control it. (Farmers' Bulletin 831.)

Carbon Disulphid as an Insecticide. (Farmers' Bulletin 799.)

Bollworm or Corn Earworm. (Farmers' Bulletin 872.)

The Argentine Ant: Distribution and Control in the United States. (Department Bulletin 377.)

The Red Spider on Cotton. (Department Bulletin 416.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

Miscellaneous Cotton Insects in Texas. (Farmers' Bulletin 223.) Price, 5 cents.

Two Destructive Texas Ants. (Entomology Circular 148.) 1912. Price, 5 cents.

Cotton Stainer. (Entomology Circular 149.) 1912. Price, 5 cents.

Cotton Worm or Cotton Caterpillar. (Entomology Circular 153.) 1912. Price, 5 cents.

Report on Miscellaneous Cotton Insects in Texas. (Entomology Bulletin 57.) 1906. Price, 5 cents.

Cotton Stalk-borer. (Entomology Bulletin 63, pt. VII.) 1907. Price, 5 cents.

Mexican Conchuela in Western Texas in 1905. (Entomology Bulletin 64, pt. I.) 1907. Price, 5 cents.

Notes on Economic Importance of Sowbugs. (Entomology Bulletin 64, pt. II.) 1907. Price, 5 cents.

Plant-bugs Injurious to Cotton Bolls. (Entomology Bulletin 86.) 1910. Price, 20 cents.

Argentine Ant. (Entomology Bulletin 122.) 1913. Price, 25 cents.

THE CORN ROOT-APHIS AND METHODS OF CONTROLLING IT

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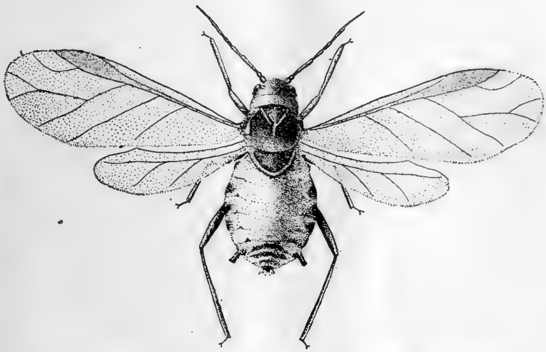

Winged female of corn root-aphis (form that produces living young). Greatly enlarged

FARMERS' BULLETIN 891
UNITED STATES DEPARTMENT OF AGRICULTURE

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

Washington, D. C. December, 1917

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CONTROL of the corn root-aphis, which can be accomplished by the simple practices described in this bulletin, is important because, in addition to corn, cotton, and asters, this insect feeds on the roots of certain weeds and everywhere is fostered by a common species of field ant.

The control measures are—

Crop rotation.

Early and deep spring plowing followed by several deep diskings to demoralize the aphid and ant colonies and to prevent the growth of weeds on which the aphis lives previous to the appearance of corn.

The use of a substance possessing a pungent odor, applied with a chemical fertilizer and distributed by means of a fertilizer attachment to the corn planter, to repel the ants and prevent them from placing aphids on the roots of the corn or other cultivated crop.

The use of barnyard manure or other fertilizer as an aid in producing stronger plants. Though this does not reduce the number of aphids, directly or indirectly, it enables the plants to withstand injury better. It is recommended only as supplementary to the practices already mentioned.

THE CORN ROOT-APHIS[1] AND METHODS OF CONTROLLING IT.

CONTENTS.

THE CORN ROOT-APHIS commits serious depredations on growing corn each year. It is very generally distributed throughout the United States east of the Rocky Mountains, but it is an especially destructive pest in the "corn belt" from Ohio to Iowa and Nebraska, including southern Wisconsin. Its abundance and destructiveness in these regions may be traced with reasonable certainty to the practice of growing two or more successive crops of corn on the same land, and this fact has a direct bearing on the practical control of the insect. It is injurious also to cotton in the South Atlantic States and to cultivated asters almost everywhere.

FIG. 1.—The corn root-aphis: Wingless female of the form that produces living young. Greatly enlarged. (Redrawn from Forbes.)

THE CORN ROOT-APHIS AND ITS INJURY.

The corn root-aphis (fig. 1) is a small, soft-bodied insect not larger than a pinhead, almost spherical when full grown, and of a bluish-green color, more or less dusted with a fine whitish powder which makes it appear grayish-green. The aphids cluster on the corn roots (fig. 2) and suck the plant juices, this continual drain acting on the plant in somewhat the same way as a drought. The greatest and most noticeable injury occurs in spring before the plants have made any considerable growth. Infested plants are dwarfed and

[1] *Aphis maidiradicis* Forbes.

the leaves become brown or otherwise discolored. Although even the heavily infested plants seldom are killed outright, usually they do not make any appreciable growth. Infestations later in the season are less noticeable and indeed seldom are recognized because the

FIG. 2.—Young corn plant showing corn root-aphids feeding on the roots.

plants as a rule are not injured outwardly. The extent of apparent damage varies with the season; conditions favoring the growth of corn sometimes enable the plants to make a fair development in spite of the insect, and an unfavorable season makes the injury unusually conspicuous.

HOW TO RECOGNIZE ROOT-APHIS INJURY.

Injury by the corn root-aphis may be distinguished from that caused by other insects if the following points are observed: (1) Root aphids usually attack corn that is grown on cornland, although occasionally other ground may develop heavy infestations if it has harbored certain weeds and likewise the aphids. (2) Injury, resulting in a stunting of the plants and yellowing of the leaves, usually occurs in early summer, when the plants are from 6 to 18 inches high. (3) Ant hills and the common brown cornfield ants are to be found at or near corn plants attacked by root aphids. (4) Plants infested with root-aphids have a complete root system, but when uprooted the bluish-green aphids will be found thickly clustered on the roots and on the underside of the crown at the base of the roots.

SEASONAL HISTORY AND HABITS.

There are four distinct forms of the corn root-aphis. The true sexes—that is to say, the males and the egg-laying females (fig. 3)—occur only in the fall. These females lay the pale yellowish-green eggs which later turn to jet black. Ants take the aphid eggs to their nests and care for them during the winter months. In spring, and continuing throughout the summer, only winged and wingless females are to be found, and these give birth to living young. (See title-page illustration and fig. 1.)

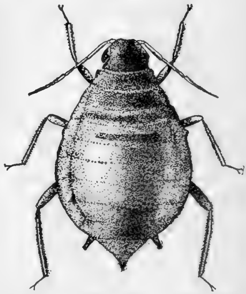


FIG. 3.—The corn root-aphis: Egg-laying female. Greatly enlarged. (Redrawn from Forbes.)

The seasonal history of this insect, which is graphically shown in figure 4, is as follows: The eggs, which are kept by the ants in their nests over winter, begin to hatch about the time smartweed seeds begin to germinate—usually the latter part of March or the first of April—and the young, frail aphids are transferred by the attentive ants to the roots of convenient weeds along which tunnels previously have been made. The aphis is able to live and reproduce on a large variety of weeds, but is most frequently to be found on such common field weeds as smartweed or knotweed,[1] crab grass,[2] purslane,[3] and foxtail or pigeon grass.[4] The young that hatch from eggs mature in about 15 days or longer and give birth to a second generation. Members of this and the succeeding generations until fall give birth to living young, which they produce without fertilization by a male. On an average about 16 or 17 generations occur from the date of hatching in the spring until fall, and the length of each generation varies according to the season, being longer in the spring and fall

[1] *Polygonum* sp.
[2] *Digitaria sanguinalis.*
[3] *Portulaca oleracea.*
[4] *Setaria* sp.

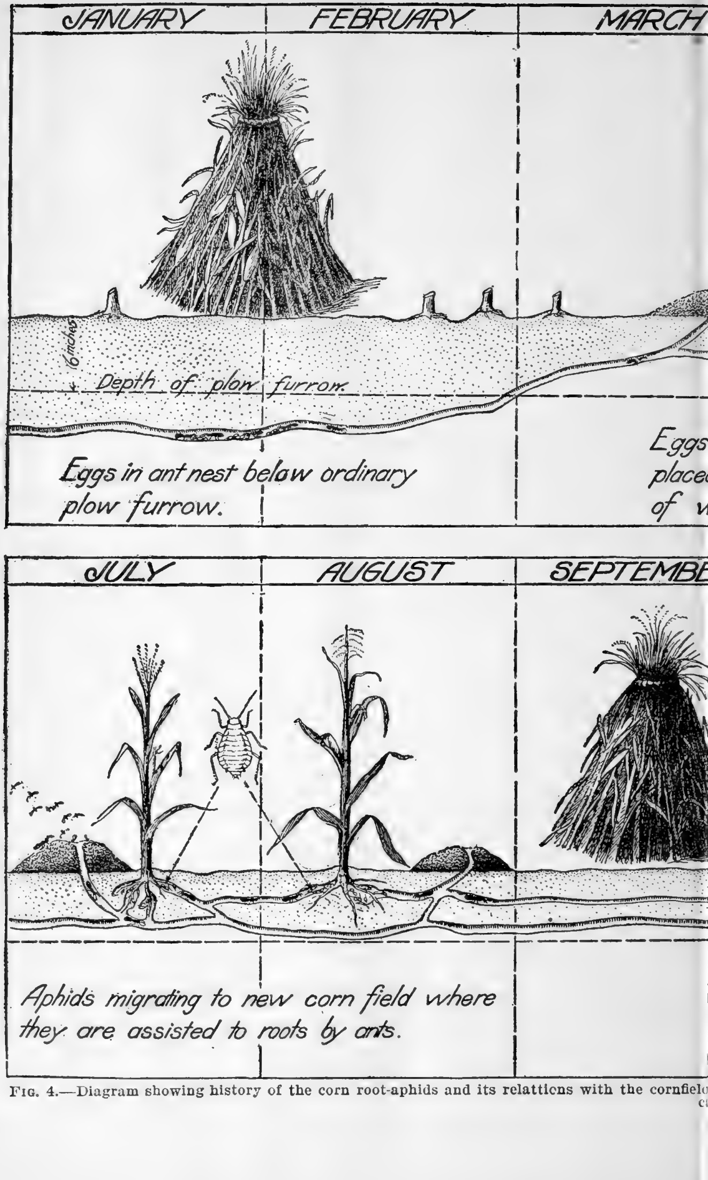
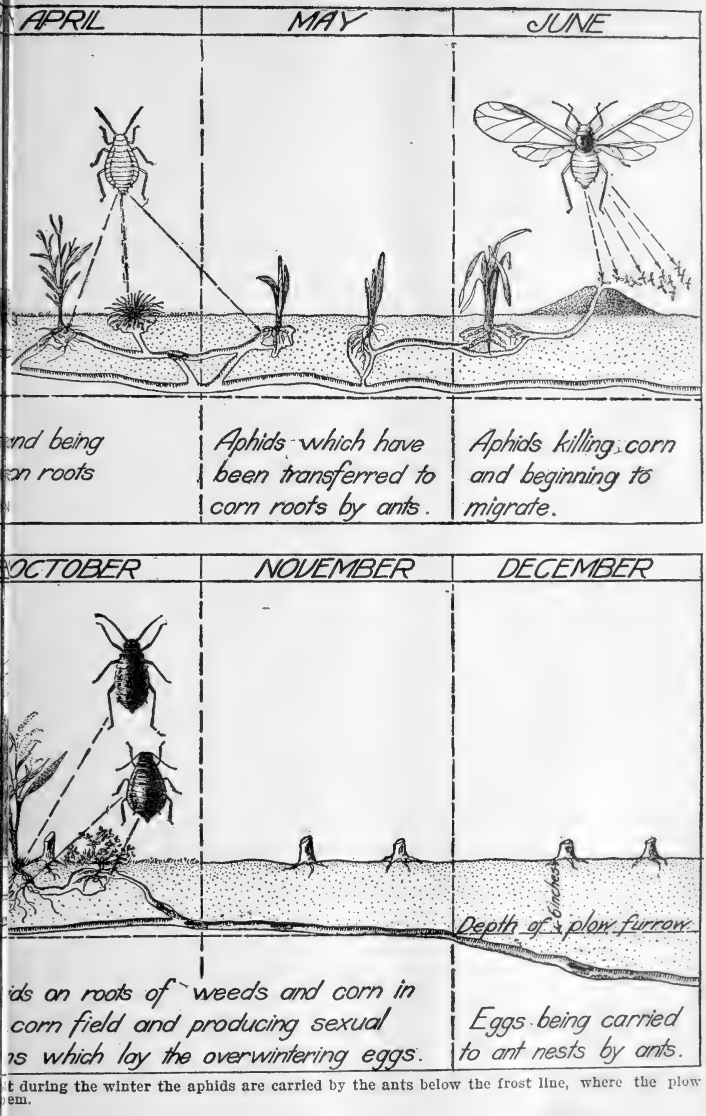


FIG. 4.—Diagram showing history of the corn root-aphids and its relattions with the cornfield



...t during the winter the aphids are carried by the ants below the frost line, where the plow ...em.

months and shorter during the summer months. Since each female gives birth to 40 or 50 young, and the young mature and themselves give birth to young in from 6 to 8 days during the summer months, it may be easily understood that they increase to enormous numbers and that the killing of one aphis early in the season is equal to the destruction of hundreds or even thousands in midsummer or later.

The first two or three generations live entirely on the roots of weeds, but as soon as the newly planted corn sprouts the ants transfer the aphids to the more succulent cornroots. Aphids are to be found on both corn and weed roots throughout the summer, wingless individuals always predominating; but after the second or third generation a considerable number of the aphids may be winged, and many of these make their exit from the ground through the ant tunnels and fly away to a new field. If they chance to alight near an ant hill, they are seized immediately by the watchful ants, carried into the burrow, and placed on a convenient root, giving rise to another infestation. Thus it happens occasionally that corn on new ground, but near heavily infested fields, becomes so badly infested in late summer, especially if the season is unfavorable to corn, that the crop is damaged noticeably—a consideration which *makes community cooperation an important measure in fighting this as well as many other field-crop pests.*

The males and the egg-laying females begin to appear about the first of October, and the eggs laid by these females are immediately stored by the attendant ants. As cold weather approaches the ants carry the eggs with their own young deeper into the soil, and usually by the middle of November, in the latitude of Illinois and Wisconsin, all will be found 8 inches or more below the surface, which is below the ordinary plow furrow—and this should be kept in mind when plowing is done in the fall in order that the ant colonies may be destroyed. Similarly in summer, during periods of drought, the ant colonies may be found 8, 10, or even 12 inches below the surface.

RELATION BETWEEN ANTS AND THE APHIDS.

As has been stated, the relation between ants and the corn root-aphis is intimate. Several species of ants are concerned, but by far the most common species occurring in fields is the small brown ant frequently spoken of as the "cornfield ant."[1] In the fall the ants carry the aphid eggs to their nests and care for them as they do for their own young, and in spring when the eggs hatch they tunnel along weed roots and place the helpless aphids on the host plant. (Fig. 5.) The aphids are cared for in the same way during the

[1] *Lasius niger* L., var. *americanus* Emery.

summer months; indeed, throughout life they are wholly dependent on the ant, which obtains in return for its work a sweetish fluid, the "predigested" sap of the corn or other plant, which is given off in considerable quantities by the aphids. Since the relationship between ants and aphids is so intimate, and since the aphids are entirely

FIG. 5.—Diagram showing how ants foster the corn root-aphis. These aphids, which are cared for by the ants in their nests during the winter, are carried through tunnels to the corn plants and placed on the roots.

dependent on the ants, it is evident that *any method which will disturb, demoralize, or destroy the ant colonies will reduce the numbers of aphids*, and this fact will be explained further in the paragraphs dealing with the means of control.

PAST HISTORY.

Previous to 1891 the corn root-aphis was generally supposed to be the subterranean form of the corn leaf-aphis,[1] which is everywhere present on corn, usually occurring beneath the leaf and ear sheath or the stalks of the unfolding tassel. As early as 1822 root-aphids, which were probably the corn root-aphids, were reported damaging corn in Pennsylvania, and in 1862 this species was definitely observed attacking corn roots and injuring the crop in Illinois. This pest has increased gradually in destructiveness until now it is recognized as one of the four or five most generally injurious insects affecting corn, for it occurs, with few exceptions, wherever this crop is grown in the United States.

[1] *Aphis maidis* Fitch.

METHODS OF CONTROL.

Most of the measures for the prevention or control of the corn root-aphis are methods which not only are effective in reducing or eradicating this and other insect pests, but constitute the more approved cultural practices and for this reason are doubly important.

ROTATION OF CROPS.

A rotation which avoids having two successive crops of corn on the same land is effective not only in preventing injury by the corn root-aphis, but also in controlling other serious pests. In the cotton belt it is important also to avoid following cotton with corn, or vice versa, since both plants are hosts of the same aphid. No other cultivated field crop is seriously affected by this insect; consequently corn may follow any other field crop with reasonable safety. Occasionally corn is damaged in spring following other crops, such as clover, but in these cases it will be found that smartweeds and other wild plants preferred by the aphis have occurred in the field in abundance the year before. Damage during late spring or summer may occur in corn following a crop other than corn or cotton, the infestations sometimes coming from neighboring heavily infested fields, but usually such damage occurs only in years unfavorable to corn growing and is of rare occurrence.

CULTURAL PRACTICES.

The most complete and effective means of controlling the corn root-aphis is thorough stirring of the soil previous to planting. The object of this procedure is to disturb the ant colonies and scatter and kill the aphids so as to permit the plants to make a substantial growth before the ant and aphid colonies can become reestablished, and in addition to prevent the growth of weeds upon which the aphids live, making it necessary for the ants to carry the surviving aphids to new fields. Infested fields which are to be replanted to corn should be plowed to a depth of 6½ or 7 inches in the spring, after March 15 in the latitude of central Indiana and Illinois; then they should have 3 or 4 diskings to a depth of 4 or 5 inches with a 16 or 20 inch disk, the number of cultivations and the intervals between them varying according to the length of the period between plowing and planting. When it is necessary to replant early injured corn the field should first be plowed deeply and thoroughly and then disked deeply 3 or 4 times at intervals of 2 or 3 days. Though these practices necessarily involve additional labor, they not only prevent injury by the corn root-aphis, but also put the field in a much better physical condition. Plowing in the fall before the ant colonies go below the plowline is sometimes as useful as spring plowing, but if warm weather follows the ants may reconstruct their nests so that replowing will be necessary in the spring. In either case the additional spring diskings are essential.

Early fall plowing followed by frequent deep diskings in fields damaged by the root-aphis that season is a good practice from the standpoint of community control, as well as for the personal benefit derived, for the plowing disturbs the ant colonies, kills many of the aphids, and destroys the weeds upon which they live, and the disking prevents the recolonization of ants and the growth of weeds. The result is a significant reduction in the number of aphid eggs—eggs being necessary to carry the insect over winter.

REPELLENTS.

Where it is impossible to practice one of the foregoing measures, an odorous substance offensive to the ants, which will prevent them from colonizing the aphids on the cornroots or will drive them from the treated field, may be used to advantage. This material does not destroy either the ants or the aphids, but tends to drive away the ants, the presence of which is essential to the life of the aphids. Oil of tansy, tincture of asafetida, oil of sassafras, anise oil, kerosene, and oil of lemon are useful for this purpose, these materials being mixed with a chemical fertilizer such as bone meal and applied by means of a planter equipped with a fertilizer attachment. They should not be applied directly on the seed, as such treatment may injure it, especially if the season be wet. Dilute one-fourth pound of oil of tansy with 2 quarts of alcohol and 1 quart of water, or 2 pints of asafetida with $1\frac{1}{2}$ gallons of water, and add either of these substances, thus diluted, to 100 pounds of bone meal, this amount being sufficient for an acre.

MAINTENANCE OF SOIL FERTILITY.

The maintenance of soil fertility by the use of barnyard manure or a commercial fertilizer has been recommended frequently, but is of value only in assisting the plants to outgrow injury either by the corn root-aphis or by any other insect which gradually affects the plant. It does not limit the number of aphids or ants, directly or indirectly, and can scarcely be included properly as a remedial or preventive measure, for if the proper soil fertility were maintained by cultivation and crop rotation excessive artificial fertilization would seldom be necessary.

COOPERATION AS AN IMPORTANT CONTROL MEASURE.

One of the greatest difficulties in the control of insects injurious to field crops is lack of community cooperation, and injury by the corn root-aphis frequently may be traced directly to this cause. The individual farmer may protect his crop from early injury by the corn root-aphis by cultivation or rotation, *but if neighboring heavily infested fields are left untreated* and the insect is permitted to live and multiply undisturbed *the migrating winged aphids may infest fields previously free from them.* This is especially likely to be the case in years when the spring weather is of such a character that it permits the root aphis to multiply but serves to delay corn planting. It is therefore important that every farmer rotate his crops and cultivate his old cornfields so as to destroy the root-aphis and the attendant ant colonies, whether he plans to replant them to corn or not. If this be done by entire communities, this pest will soon be classed among the corn insects of minor importance or among those known to be only occasionally injurious.

PUBLICATIONS OF UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO INSECTS INJURIOUS TO CEREAL AND FORAGE CROPS, AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Common White Grubs. (Farmers' Bulletin 543.)
Larger Corn Stalk-borer. (Farmers' Bulletin 634.)
Chalcis-fly Alfalfa Seed. (Farmers' Bulletin 636.)
Grasshopper Problem and Alfalfa Culture. (Farmers' Buletin 637.)
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Alfalfa Attacked by Clover-root Curculio. (Farmers' Bulletin 649.)
Chinch Bug. (Farmers' Bulletin 657.)
Wireworms Destructive to Cereal and Forage Crops. (Farmers' Bulletin 725.)
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Cutworms and their Control in Corn and other Cereal Crops. (Farmers' Bulletin 739.)
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Bollworm or Corn Earworm. (Farmers' Bulletin 872.)
Rough-headed Corn Stalk-beetle in Southern States and its Control. (Farmers' Bulletin 875.)
Corn Root-aphids and Methods of Controlling It. (Farmers' Bulletin 891.)
Western Corn Rootworm. (Department Bulletin 8.)
Oat Aphis. (Department Bulletin 112.)
Alfalfa Caterpillar. (Department Bulletin 124.)
Wireworms Attacking Cereal and Forage Crops. (Department Bulletin 156.)
Sharp-headed Grain Leafhopper. (Department Bulletin 254.)
Desert Corn Flea-beetle. (Department Bulletin 436.)
New Mexico Range Caterpillar and its Control. (Department Bulletin 443.)
Two Destructive Texas Ants. (Entomology Circular 148.)

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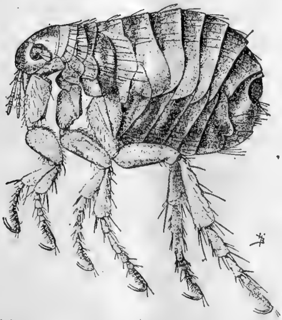
FLEAS AND THEIR CONTROL

F. C. BISHOPP

Entomologist, Insects Affecting the Health of Animals



Adult Female of the Human Flea, Greatly Enlarged

FARMERS' BULLETIN 897

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

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OF THE APPROXIMATELY 500 species of fleas known to exist, less than one dozen are of special interest as pests to man and domestic animals, but any individual of one of these few species, when bent upon satisfying its appetite, fully occupies the attention of its chosen host.

The human flea, dog flea, cat flea, sticktight flea or chicken flea, and the rat fleas (which carry the bubonic plague), are the principal species that annoy man and domestic animals in the United States.

The main steps in control, as described in this bulletin, are the elimination of breeding places and the destruction of fleas on the infested animals. If breeding places receive proper attention the premises often will be cleared of fleas, even though little or no attention is given to the animals themselves.

Fleas breed in greatest numbers in accumulations of vegetable and animal matter protected from wind and rain, but at the same time furnished with shade and a certain amount of moisture. All live stock should be prevented from going beneath buildings, the vegetable and animal matter carefully cleaned up, and the ground where the immature fleas are developing covered with salt and thoroughly wet down. House infestations may be prevented by eliminating pet animals and applying gasoline to the floors after all rugs have been removed and the floors thoroughly scrubbed with soap and water. Washing pet animals in a comparatively weak solution of saponified creosote or kerosene emulsion will destroy the fleas upon them.

FLEAS AND THEIR CONTROL.

CONTENTS.

FLEAS AFFECT US IN TWO WAYS: First, as disease carriers, and, second, as parasites or annoyers of man and animals. The dread 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 and then to gain entrance to a new host by the swallowing of crushed or living fleas. The present war, with its movement of vast bodies of troops between various parts of the world, has its attendant danger of spreading disease, and it is probable that the dangers along this line will be multiplied when peace is reestablished, owing to extensive immigration and the unsettled conditions that will prevail in various countries.

Aside from the transmission of diseases fleas are of considerable importance as parasites of man and animals. 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.

Fleas are of many kinds. Most of them, however, 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. For example, the dog flea (fig. 1)[1] normally feeds on dogs and cats,

[1] The fleas mentioned in this bulletin are known scientifically as follows: Dog flea, *Ctenocephalus canis* Curtis; cat flea, *Ctenocephalus felis* Bouché; 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 flea, *Echidnophaga gallinaceus* Westw.

but 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 these fleas are the ones ordinarily responsible for the inoculation of man with bubonic plague.

Fleas of different species vary markedly in the intimacy with which they are associated with their hosts. Some kinds remain upon host animals practically all 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 the 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 and feed only at intervals. The human flea remains upon man but little, being elsewhere the greater portion of the time.

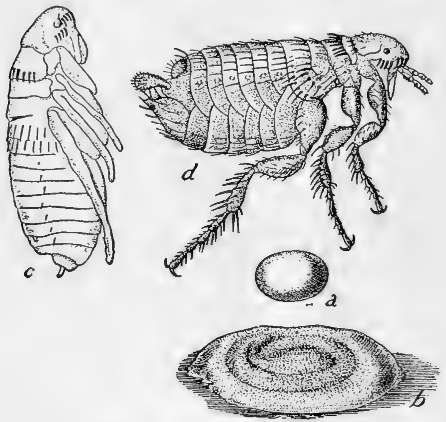

FIG. 1.—The dog flea: *a*, Egg; *b*, larva in cocoon; *c*, pupa; *d*, adult. *b*, *c*, *d*, Much enlarged; *a*, more enlarged. (Howard.)

The life of the flea has four distinct stages, as is the case with many other insects; these stages are the egg, larva, pupa, and adult.

A number of eggs are deposited by each adult female flea. The egg laying, alternated with feeding, extends over a considerable time. In most cases the eggs are deposited by the fleas while the latter are on the animal 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 cream-colored or white and ovoid. Large numbers of them often may be seen on mats or cushions upon which infested dogs or cats sleep. Especially are they easily observed when on dark-colored cloths. Hatching usually takes place from 2 to 12 days.

The larva when first hatched is whitish, very minute, and quite active. (See fig. 2, larva of European rat flea.) In this stage fleas are not 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 pupa or resting stage.

The insect remains within the cocoon for a period which may range from three days to more than a year.

The complete life cycle of members of this group of insects may be passed in as short a period as 17 days, but during cool weather or under adverse conditions the total period from egg to adult may extend considerably over a year.

LENGTH OF LIFE OF THE ADULT.

The length of life of the mature flea varies much as between different species and under different atmospheric conditions. During hot, dry weather, and when no animals upon which to feed are present, the duration of life may be extremely short—from 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 summer probably the average longevity of the human flea without food is about two months, of the dog flea somewhat less, and of the sticktight flea still less.


FIG. 2.—The European rat flea: Larva. Greatly enlarged.

ABUNDANCE OF FLEAS, WITH 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. In the extreme Southern States this is not always true, as much trouble from the human, dog, and sticktight fleas has been observed to occur in late spring or early summer when rains were frequent and the humidity high.

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. The larva and pupa require a certain amount of moisture for successful development, and the adults live longer when a proper degree of moisture is present. It would be erroneous, however, to infer from this that fleas require very moist places in which to breed; in fact excessive moisture in the breeding places is as detrimental as is excessive dryness. This sensitiveness to excessive moisture can be utilized in remedial work, as will be pointed out later.

It is common knowledge that fleas occur in greatest abundance in sandy regions. This is explained by the fact that sand maintains moisture more uniformly, 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 the pests.

FIG. 3.—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 (title-page).

In portions of the South and West the human flea (title-page illustration and fig. 3) 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. When comparatively small numbers of fleas are found on people in houses, breeding places should be sought out of doors in sheds or barns frequented by dogs and cats, especially if the house is kept clean and animals do not frequent it.

The conditions which give rise to severe outbreaks in houses, particularly in the case of the dog or cat fleas, 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 unchecked, so that at about the time the occupants return the fleas have reached the adult stage. In the absence of other hosts they are exceedingly hungry and ready to attack man or any animals which are accessible.

[1] Howard, L. O. House Fleas. U. S. Dept. Agr. Bur. Ent. Cir. 108, 4 p., 2 figs., Feb 11, 1909.

Some infestations of residences come from breeding places beneath the houses. The fleas in these cases usually are 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 in which such infestations have extended 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 severe than in the extreme cases above mentioned, and the breeding places often are more widely extended.

A number of instances in the Southern and Central Western States have come to notice in which hogs appear to have been the source of gross infestations by the human flea. The adult fleas feed on the hogs and breeding takes place in the beds of these animals. In some instances the source of infestation is in the hog runs, but more usually it is derived from hogs sleeping under houses or in barns.

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 been noted 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 (figs. 4, 5), probably is 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 4 illustrates the usual mode of infestation on a chicken's head, and figure 5 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.

This flea is most common and is 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 the 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. They require comparatively dry material in which to breed, but a large amount of air moisture is favorable to them. Adults of this species continue to emerge from infested trash for four or five months after all hosts have been removed; hence it is easy to understand why chicken

FIG. 4.—Head of rooster infested with the sticktight flea. Reduced.

FIG. 5.—The sticktight flea: Adult female. Much enlarged.

houses may still have many fleas in them after being unused for considerable periods.

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 persons entering chicken houses and being attacked by them. 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 methods outlined on pages 10–14.

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

[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.

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. In the case of valuable dogs and cats, however, 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 5 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 produced 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.

THE RELATION OF FLEAS 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 has persisted for a number of years, although 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.

During the year 1914 the disease broke out in New Orleans, but strict quarantine measures and an energetic campaign against the rats[1] kept the malady from spreading and limited the number of human cases.

With the reduction in numbers of rats and mice there is a correspondingly great decrease in the numbers of the species of fleas which infest them and which may play a part in carrying bubonic plague. The cleaning up of the breeding places of rats and the destruction of their nests will accomplish the extermination of a large number of fleas in the immature stages.

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.

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[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.

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.

REMEDIES FOR 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 therefore is apparent at once 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.

HOW TO KILL 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 scrubbed thoroughly, special precaution being taken 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 should 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 washing cleanses and deodorizes the fur and also aids in the healing of any wounds which are present.

The thorough washing of infested animals in kerosene emulsion is a cheap and satisfactory method of destroying fleas. Five gallons of this emulsion may be made by dissolving 2 ounces of washing soap in 1 quart of hot water and when brought to a boil removing it from the fire and adding 2½ pints of kerosene. The mixture should be agitated violently with an egg-beater or something of the sort. This should result in a milky mass from which the oil does not separate. Water is then added to make 5 gallons. Free kerosene will burn animals, and if any separates out the mixture should be reheated, care being taken to avoid spilling it on the fire or boiling it over, and then it should be beaten again.

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.

The skin of cats is much more easily injured with chemicals than that of dogs; hence, any preparation used should be weaker when used on cats than on dogs.

Fleas on hogs may be destroyed by dipping the animals in a vat containing one of the creosote dips 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 that all animals be kept 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 inforcement 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.

HOW TO DESTROY FLEAS IN IMMATURE STAGES.

Following the ridding of infested animals of adult fleas, it is important to destroy the immature fleas, which are constantly becoming full grown and reinfesting animals and annoying man.

Sometimes when adult fleas are very numerous it is advisable to destroy some of them before proceeding to destroy the young. Out of doors or in barns or chicken houses this may be done by spraying the ground and the lower parts of the walls with kerosene emulsion or pure kerosene. In houses the use of flaked naphthalene as described in a later paragraph will permit the work of cleaning to proceed without annoyance from adult fleas.

In household infestations usually it is 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. Then the floor should be scrubbed with strong soapsuds or sprinkled with gasoline, care being taken to avoid having fires about during the 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 floors, which facilitate frequent sweeping and make 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 the doors and windows tightly for 24 hours. After this period 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 kills all fleas present and in addition destroys the rats and mice. When sulphur is to be employed 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, 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-shaped mass in a good-sized pan or kettle and placed in a larger pan containing water to avoid danger of fire from the heat generated. As sulphur will not burn readily at first a little alcohol is poured into a depression made in the top of the cone, 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 from burning sulphur corrodes metals and injures plants, it is necessary to remove metal objects and potted plants before fumigation. It is not advisable for anyone to undertake the use of hydrocyanic-acid gas without obtaining the complete directions for its employment contained in Farmers' Bulletin 699, entitled "Hydrocyanic-Acid Gas Against Household Insects." This gas is very poisonous, but it 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. Then common salt should be scattered about and thoroughly wet down. A second wetting two or three days later usually will accomplish complete destruction, but if this is not found sufficient, one or two additional wettings may be given. Where crude petroleum is cheap and especially where water can not be applied easily, sprinkling the ground with a liberal amount of this oil will give good results. 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 FLEAS.

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 possible, therefore, 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. It is also possible to keep fleas out by placing the legs of the bed in pans of water covered with a film of kerosene, if the bedding is prevented from reaching near the floor

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 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 a good distance from the buildings and scattered. The places where the fleas are thought to be breeding should then be sprinkled with crude oil. 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. 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. *Fowls should not be permitted to eat the salt, as it is poisonous to them.*

It is rather difficult to destroy the sticktight flea on fowls 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—1 part kerosene to 2 parts lard. In all cases care should be taken that the applications of grease are confined to 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 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 doing 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 FLEA BITES.

In regions in the United States where the plague is not known to occur no special concern need be felt regarding flea bites. 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 the case of susceptible individuals, 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.

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FLEAS and Their Control

F. C. BISHOPP
ENTOMOLOGIST, INSECTS AFFECTING THE HEALTH OF ANIMALS

Adult Female of the Human Flea, Greatly Enlarged

FARMERS' BULLETIN 897
UNITED STATES DEPARTMENT OF AGRICULTURE

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1921

OF THE APPROXIMATELY 500 species of fleas known to exist, less than one dozen are of special interest as pests to man and domestic animals, but any individual of one of these few species, when bent upon satisfying its appetite, fully occupies the attention of its chosen host.

The human flea, dog flea, cat flea, sticktight flea or chicken flea, and the rat fleas (which carry the bubonic plague), are the principal species that annoy man and domestic animals in the United States.

The main steps in control, as described in this bulletin, are the elimination of breeding places and the destruction of fleas on the infested animals. If breeding places receive proper attention the premises often will be cleared of fleas, even though little or no attention is given to the animals themselves.

Fleas breed in greatest numbers in accumulations of vegetable and animal matter protected from wind and rain, but at the same time furnished with shade and a certain amount of moisture. All live stock should be prevented from going beneath buildings, the vegetable and animal matter carefully cleaned up, and the ground where the immature fleas are developing covered with salt and thoroughly wet down. House infestations may be prevented by eliminating pet animals and applying gasoline to the floors after all rugs have been removed and the floors thoroughly scrubbed with soap and water. Washing pet animals in a comparatively weak solution of saponified creosote or kerosene emulsion will destroy the fleas upon them.

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C.

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FLEAS AND THEIR CONTROL.

CONTENTS.

FLEAS AFFECT US IN TWO WAYS: First, as disease carriers, and, second, as parasites or annoyers of man and animals. The dread 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 and then to gain entrance to a new host by the swallowing of crushed or living fleas. The recent war, with its movement of vast bodies of troops between various parts of the world, had its attendant danger of spreading disease, and it is probable that the dangers along this line are just as acute now, owing to the unsettled conditions that prevail in various countries.

Aside from the transmission of diseases fleas are of considerable importance as parasites of man and animals. 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.

Fleas are of many kinds. Most of them, however, 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. For example, the dog flea (fig. 1)[1] normally feeds on dogs and cats,

[1] The fleas mentioned in this bulletin are known scientifically as follows: Dog flea, *Ctenocephalus canis* Curtis; cat flea, *Ctenocephalus felis* Bouché; 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 flea, *Echidnophaga gallinaceus* Westw.

but 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 these fleas are the ones ordinarily responsible for the inoculation of man with bubonic plague.

Fleas of different species vary markedly in the intimacy with which they are associated with their hosts. Some kinds remain upon host animals practically all 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 the 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 and feed only at intervals. The human flea remains upon man but little, being elsewhere the greater portion of the time.

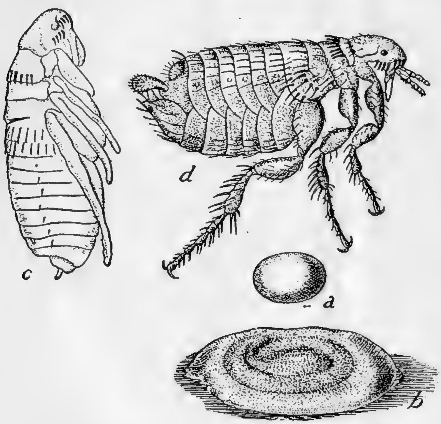

FIG. 1.—The dog flea: *a*, Egg; *b*, larva in cocoon; *c*, pupa; *d*, adult. *b*, *c*, *d*, Much enlarged; *a*, more enlarged. (Howard.)

The life of the flea has four distinct stages, as is the case with many other insects; these stages are the egg, larva, pupa, and adult.

A number of eggs are deposited by each adult female flea. The egg laying, alternated with feeding, extends over a considerable time. In most cases the eggs are deposited by the fleas while the latter are on the animal 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 cream-colored or white and ovoid. Large numbers of them often may be seen on mats or cushions upon which infested dogs or cats sleep. Especially are they easily observed when on dark-colored cloths. Hatching usually takes place from 2 to 12 days after deposition.

The larva when first hatched is whitish, very minute, and quite active. (See fig. 2, larva of European rat flea.) In this stage fleas are not 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 twice, and between four days and several months after hatching a silken cocoon is spun, and in this the larva transforms to the pupa or resting stage.

The insect remains within the cocoon for a period which may range from three days to more than a year.

The complete life cycle of members of this group of insects may be passed in as short a period as 17 days, but during cool weather or under adverse conditions the total period from egg to adult may extend considerably over a year.

LENGTH OF LIFE OF THE ADULT.

The length of life of the mature flea varies much as between different species and under different atmospheric conditions. During hot, dry weather, and when no animals upon which to feed are present, the duration of life may be extremely short—from 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 summer probably the average longevity of the human flea without food is about two months, of the dog flea somewhat less, and of the sticktight flea still less.

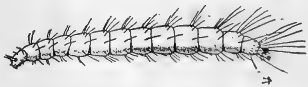

FIG. 2.—The European rat flea: Larva. Greatly enlarged.

ABUNDANCE OF FLEAS, WITH 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. In the extreme Southern States this is not always true, as much trouble from the human, dog, and sticktight fleas has been observed to occur in late spring or early summer when rains were frequent and the humidity high.

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. The larva and pupa require a certain amount of moisture for successful development, and the adults live longer when a proper degree of moisture is present. It would be erroneous, however, to infer from this that fleas require very moist places in which to breed; in fact excessive moisture in the breeding places is as detrimental as is excessive dryness. This sensitiveness to excessive moisture can be utilized in remedial work, as will be pointed out later.

It is common knowledge that fleas occur in greatest abundance in sandy regions. This is explained by the fact that sand maintains moisture more uniformly, 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 the pests.

FIG. 3.—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 (title-page).

In portions of the South and West the human flea (title-page illustration and fig. 3) 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. When comparatively small numbers of fleas are found on people in houses, breeding places should be sought out of doors in sheds or barns frequented by dogs and cats, especially if the house is kept clean and animals do not frequent it.

The conditions which give rise to severe outbreaks in houses, particularly in the case of the dog or cat fleas, 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 may have been closed up during a vacation period and the breeding allowed to proceed unchecked, so that at about the time the occupants return the fleas have reached the adult stage. In the absence of other hosts they are exceedingly hungry and ready to attack man or any animals which are accessible.

[1] Howard, L. O. House Fleas. U. S. Dept. Agr. Bur. Ent. Cir. 108, 4 p., 2 figs., Feb. 11, 1909.

Some infestations of residences come from breeding places beneath the houses. The fleas in these cases usually are 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 in which such infestations have extended 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 severe than in the extreme cases above mentioned, and the breeding places often are more widely extended.

A number of instances in the Southern and Central Western States have come to notice in which hogs appear to have been the source of gross infestations by the human flea. The adult fleas feed on the hogs and breeding takes place in the beds of these animals. In some instances the source of infestation is in the hog runs, but more usually it is derived from hogs sleeping under houses or in barns.

FLEAS INJURIOUS TO POULTRY AND DOMESTIC ANIMALS.

Fortunately the higher domestic animals are comparatively free from flea attacks. Horses, cattle, sheep, and goats are seldom seriously annoyed, although a few instances have been noted in which the sticktight flea infested horses, and mules and horses are sometimes worried considerably by the human flea and may refuse to stay in infested barns even long enough to eat. Hogs are infested to some extent, but seldom heavily enough to do any great damage.

THE STICKTIGHT FLEA.

The sticktight flea, or southern chicken flea (figs. 4, 5), probably is 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 4 illustrates the usual mode of infestation on a chicken's head, and figure 5 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.

This flea is most common and is 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 the 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. They require comparatively dry material in which to breed, but a large amount of air moisture is favorable to them. Adults of this species continue to emerge from infested trash for four or five months after all hosts have been removed; hence it is easy to understand why chicken

FIG. 4.—Head of rooster infested with the sticktight flea. Reduced.

FIG. 5.—The sticktight flea: Adult female. Much enlarged.

houses may still have many fleas in them after being unused for considerable periods.

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 persons entering chicken houses and being attacked by them. 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 methods outlined on pages 10–14.

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

[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.

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. In the case of valuable dogs and cats, however, 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 5 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 produced 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.

THE RELATION OF FLEAS 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 has persisted for a number of years, although 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.

During the year 1914 the disease broke out in New Orleans, but strict quarantine measures and an energetic campaign against the rats[1] kept the malady from spreading and limited the number of human cases.

With the reduction in numbers of rats and mice there is a correspondingly great decrease in the numbers of the species of fleas which infest them and which may play a part in carrying bubonic plague. The cleaning up of the breeding places of rats and the destruction of their nests will accomplish the extermination of a large number of fleas in the immature stages.

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.

[1] The methods of rat control are discussed in Farmers' Bulletin 896, U. S. Department of Agriculture, by Mr. D. E. Lantz, of the Bureau of Biological Survey.

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.

REMEDIES FOR 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 therefore is apparent at once 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.

HOW TO KILL 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 scrubbed thoroughly, special precaution being taken 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 should 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 washing cleanses and deodorizes the fur and also aids in the healing of any wounds which are present.

The thorough washing of infested animals in kerosene emulsion is a cheap and satisfactory method of destroying fleas. Five gallons of this emulsion may be made by dissolving 2 ounces of washing soap in 1 quart of hot water and when brought to a boil removing it from the fire and adding $2\frac{1}{2}$ pints of kerosene. The mixture should be agitated violently with an egg-beater or something of the sort. This should result in a milky mass from which the oil does not separate. Water is then added to make 5 gallons. Free kerosene will burn animals, and if any separates out the mixture should be reheated, care being taken to avoid spilling it on the fire or boiling it over, and then it should be beaten again.

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.

Recent experiments with the use of the powdered roots of certain tropical plants known as derris indicate that this drug when fresh is exceedingly effective in destroying fleas on animals. All fleas on a dog will be destroyed by one application of 1 gram or about three-fourths of a level teaspoonful of the powder. It is suggested that the material be mixed at the time it is used with two parts of flour or cornstarch and dusted into the hair of the animal, especially along the back and neck, with a shaker.

The skin of cats is much more easily injured with chemicals than that of dogs; hence, any preparation used should be weaker when used on cats than on dogs.

Fleas on hogs may be destroyed by dipping the animals in a vat containing one of the creosote dips 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 that all animals be kept 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.

HOW TO DESTROY FLEAS IN IMMATURE STAGES.

Following the ridding of infested animals of adult fleas, it is important to destroy the immature fleas, which are constantly becoming full grown and reinfesting animals and annoying man.

When adult fleas are very numerous it is advisable to kill them before proceeding to destroy the young. Experiments of a practical nature prove that very striking results may be accomplished by the spraying of an infested area, whether in a basement, chicken house, barn, or feed lot, with creosote oil. A light spraying kills the adult fleas almost instantly and apparently has some destructive effect on the immature stages.

Creosote oil is derived from coal tar and is used as a wood preservative. It is comparatively cheap, retailing at about 50 cents per gallon. Unfortunately it is not generally available at present and it is somewhat variable in composition, especially in regard to the amount of tar acids present. The best results are secured with a product containing from 12 to 20 per cent tar acids. Where there is grass or shrubbery to be considered, kerosene emulsion should be substituted for the creosote oil, which will kill vegetation. Care should also be taken not to strike animals directly with the material, as it is rather caustic. In houses the use of flaked naphthalene as described in a later paragraph will permit the work of cleaning to proceed without annoyance from adult fleas.

In household infestations usually it is 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. Then the floor should be scrubbed with strong soapsuds or sprinkled with gasoline, care being taken to avoid having fires about during the 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 floors, which facilitate frequent sweeping and make 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 the doors and windows tightly for 24 hours. After this period 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 kills all fleas present and in addition destroys the rats and mice. When sulphur is to be employed 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, 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-shaped mass in a good-sized pan or kettle and placed in a larger pan containing water to avoid danger of fire from the heat generated. As sulphur will not burn readily at first a little alcohol is poured into a depression made in the top of the cone, 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 from burning sulphur corrodes metals and injures plants, it is necessary to remove metal objects and potted plants before fumigation. It is not advisable for anyone to undertake the use of hydrocyanic-acid gas without obtaining the complete directions for its employment contained in Farmers' Bulletin 699, entitled "Hydrocyanic-Acid Gas Against Household Insects." This gas is very poisonous, but it 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. Then common salt should be scattered about and thoroughly wet down. A second wetting two or three days later usually will accomplish complete destruction, but if this is not found sufficient, one or two additional wettings may be given. Where crude petroleum is cheap and especially where water can not be applied easily, sprinkling the ground with a liberal amount of this oil will give good results. 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 FLEAS.

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 heading, "How to kill fleas on cats, dogs, and hogs" (p. 10). In districts where the plague is known to exist and it is desirable to catch the few fleas 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 possible, therefore, 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. It is also possible to keep fleas out by placing the legs of the bed in pans of water covered with a film of kerosene, if the bedding is prevented from reaching near the floor.

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 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 a good distance from the buildings and scattered. The places where the fleas are thought to be breeding should then be sprinkled with crude oil. 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. 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. *Fowls should not be permitted to eat the salt, as it is poisonous to them.*

It is rather difficult to destroy the sticktight flea on fowls 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—1 part kerosene to 2 parts lard. In all cases care should be taken that the applications of grease are confined to 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 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 doing 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 FLEA BITES.

In regions in the United States where the plague is not known to occur no special concern need be felt regarding flea bites. 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 the case of susceptible individuals, 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.